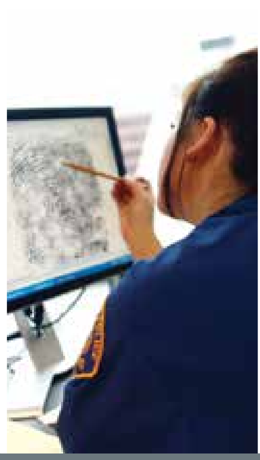
EXEMPLARY SCIENCE

Exemplary College Science Teaching



Edited by Robert E. Yager

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Preface

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Recognizing exemplary practices in the college science classroom was the primary motivation for the establishment of the Society for College Science Teachers (SCST) on March 24, 1979, in Atlanta, Georgia, during an NSTA national conference. The founders of SCST wanted an organization dedicated to the improvement in the teaching of college science courses through interdisciplinary collaboration between teachers of college science. In April, 1981, SCST became an official affiliate of NSTA and started providing college-level NSTA members increased services to help them to reach their personal objectives as well as those of the profession.

Monographs such as "Exemplary College Science Teaching" represent one way NSTA and SCST collaborate to serve college instructors. It truly reflects SCST's interdisciplinary approach to studying and promoting the advancement of college science teaching. This monograph is dedicated to the community of college and university teaching scholars who are working to enhance science education through the development and testing of best classroom teaching practices.

Recently, I came across an excerpt from an unlikely reference while surfing the internet for information about the history of college science teaching. It was in a book called *The Scottish Connection: The Rise of English Literary Study in Early America*, written by Franklin E. Court in 2001. Court described the criteria for best practices in a college education for 1803 as the ability to recite hundreds of pages of facts and rules.

My further investigations into past science education literature showed this to be the norm from 1803 to the 1920s. Critical analyses of college education by educational researchers steadily grew from the 1920s to the 1950s. By the 1940s, educational researchers were downplaying the value of rote memorization in science teaching. The ideas of John Dewey fueled a new way of instruction called progressive education (Westbrook 1991).

It appears that Dewey, and other education reformers, were more effective at communicating their ideology to the K–12 educators. College teachers were encouraged to teach content in an environment that fostered exploratory learning and relevance. Plus, they applied rational assessment models as formulated in Benjamin Bloom's classification of educational objectives (1956). The infrastructure of the reform movement had the following elements:

- Lead the student to become aware of a problem (or gap in information to resolve an issue).
- Direct the student to define the problem.
- Have the student formulate rational hypotheses to resolve the problem.
- Lead the student to evaluate the consequences of the different hypotheses based on supported evidence.
- Encourage the student to test the likeliest solution typically as a group discussion.

This "innovative" instructional methodology showed measurable successes at improving the quality of education and led to the funding of many progressive science teaching strategies by the National Science Foundation. It also gained support by most state education departments and was becoming the prevailing educational model of the United States Department of Education.

Unfortunately, higher education did not adopt progressive educational strategies until the new educational paradigm was established in K–12 schools. The model of college rote content area "expertise" was considered the prevailing formula for success. Student success is currently the "buzzword" in college science teaching; accreditation and funding entities now look for systematic pedagogical strategies that foster student success in college. Each manuscript in this monograph is derived from the contemporary need to improve college science education. Plus, many of the authors are SCST members who long ago were promoting best practices in college science teaching.

As you read this monograph, think about the following questions about your teaching. What type of instructional model are you using in your classroom? Is it contributing to student success in discipline area and does it inculcate lifelong skills? How do you learn about new trends in science education and do they really improve college science teaching? What is your role to society as a science educator? Is your instructional strategy promoting workforce skills in the sciences? Is your department and is your administration supportive of excellence in teaching? Does your college or university encourage the explorations of novel teaching strategies?

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Foreword

Exemplary College Science Teaching: Helping or Hindering STEM Reforms?

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Problems With Most College Science Teaching

Finally we come to grips with the cause for needed reforms of science education that include the college level! For some reason few have questioned the teaching of college science courses and how it models teaching for those who aspire to teach in K–12 schools. Elementary education students frequently do not feel interested, successful, or positive with their performances in science classes they have experienced in high school or college. Yet the attitude and creativity found in students in elementary schools result in most positive views regarding science learning! Too many future teachers in middle and high schools often merely mimic what they experienced in college. Ironically, the lack of experience with college science results in more positive attitudes about "doing" science at the elementary level, especially when teachers admit to not knowing!

The worst problem in terms of school science is the efforts at the upper high school levels, where only half of the students complete any science courses, often in chemistry and physics. These two offerings at 11th and 12th grades are too often labeled as college preparation courses, where the assumption is that the teaching should model what characterizes these disciplines in colleges.

College science teaching usually does not focus on how the content would be used for various courses in secondary schools. There is rarely any attempt to focus on student learning and how teaching and the curriculum might be affected by college instructors. In fact, most were concerned that most grade 5–12 science teachers had not completed enough college coursework to qualify them to teach science. Major NSF funding for science teachers often focused on completing more coursework in science as a way to improve. There was little or no focus on *how* science was done or for understanding how "doing" real science could help in resolving personal and societal problems. "Doing" science goes beyond what is done or what most researchers do in their own laboratories. Paul DeHart Hurd noted in 1980 that science had become primarily a collaborative undertaking concerning how the natural world could be studied. Hurd reported that one effort published in France included more pages of the names of scientists who contributed than pages actually devoted to report the research findings.

College teaching is too often offered as only something done by speaking (lecturing) to students about the ideas and theories describing the universe in discipline formats, as is commonly found in courses in physics, chemistry, and biology. In addition to lecturing, most college scientists include some descriptions of their experiences in the laboratories. These experiences are meant to serve as ways of portraying the science done by scientists, and offer other views concerning relationships of "learning" what was presented in lectures. There is often little or no "hands-on" learning science itself or any use of the materials presented. In many ways college science is offered as what current scientists accept as accurate interpretations of the features of nature as described by "experts," sometimes with their supporting evidence (proof). There is often no action to encourage students to think and do other than remember what they were told (like following a recipe in cooking)!

It is only recently that college teaching has been analyzed and alternative suggestions tried. This is what the Exemplary Science Program (ESP) encourages all to consider. The results concerning such thoughts and ideas that have been tried are reported in the 16 chapters of this monograph at a time when new reforms are being considered (STEM).

The first chapter is offered as the experience and pathway of a science teacher questioning the typical repeating of what was experienced in college as a teaching model. It sets the stage for the many changes needed and undertaken—probably by many of the authors of the following chapters. For reforms to succeed, many more trials, features, and questions must be a focus. The hope is that this monograph and the 16 exemplars will enlarge, encourage, and support changes in college science teaching!

Engaging Students in Actually "Doing" Science

Research about student learning highlights the fact that real learning is focused on thinking, analyzing, and personally constructing meaning. Gee (2011) identified several researchers in the late 1950s and early 1960s that helped develop the constructivist theory of learning. These researchers include Bruner, von Glasersfeld, Gergen, Piaget, and Vygotsky. The aspects of constructivist theory have been offered as variations, including radical constructivism, social constructivism, and social cultural constructivism. In general, constructivists believe that learners construct knowledge rather than merely receiving it; and this act of construction is greatly dependent on the prior knowledge and experience that the learner brings to the task. Von Glasersfeld (1995) explains that from the constructivist perspective, learning is not a stimulus response phenomenon. It requires self-regulation and the building of conceptual structures through reflection and abstraction. Generally constructivist practices consist of

1. posing problems of emerging relevance to learners or expect students to question themselves;
2. structuring learning around "big ideas" or primary concepts;
3. seeking and valuing students' points of view;
4. adapting curriculum to address student suppositions; and
5. assessing student learning in the context of teaching.

Students should be encouraged to start with problems and questions. Science itself begins with questions, followed by encouraging and expecting others to identify multiple forms of evidence that might offer answers. Students are expected to consider as many answers as possible. These can be compared among students in a given classroom. Next is a discussion of ways of testing the accuracy of the ideas generally. Again, unique results provide settings for more student examples. Perhaps many of them are never mentioned previously or in all class sections.

It is important for teachers to reject the idea that science is something that can be transmitted directly to students. Too often teachers only expect students to repeat what textbooks or teachers say. This can be done in ways like they are the parts from a school class play. The more students are involved, the more they are like the actors mirroring "doing" science better. For learning to succeed, students must work to understand and use their efforts in order for them to indicate success with learning experiences. Most teachers, however, are willing to accept verbatim definitions students can remember from teacher statements or books as verifications. What happens when results of lab activities are given? They are too often simply explanations from a lab manual. Many of the chapters included in this monograph report on the inclusion of community members who can help with actually engaging students in the processes of science itself.

Local Issues and Happenings

Too often the materials included in a lecture, in a directive lab, or as ways of assessing science learning are not related to any real-life use. Community involvement is rarely related to anything beyond what comprises a lecture, outside assignment, or a lab. Science teachers should be instrumental in noting actions and happenings that affect the whole community, that respond to specific problems, or that illustrate ties to a given issue. Too often the curriculum, content covered, and laboratories are unrelated to what students can use—especially in new situations. Effective college teaching particularly must relate to the content and procedures found in communities, where both teachers and students work. Application of lecture explanations and lab activities should provide new contexts that illustrate real learning.

Some teachers like to introduce a problem with immediate ties to a planned laboratory, relating such labs to local businesses, environmental issues, and/or recent local concerns (new reports). Too often the stated problem is a statement given by teachers that offers little impact or interest for all students. Again, students can help! There are differences among students in science classes. Teachers should take advantage of such differences among students by sharing excitement, ideas, problems, probable conclusions, and actions as ways of promoting student thinking and learning!

Teachers use plans, teaching topics, textbooks, and laboratories that too often do not provide and enhance planning, interest, action, or use in the specific communities. Encouraging students to compare activities and actions should occur frequently. Colleges have an advantage of drawing more students into classes than what can be tried in K–12 communities. Teachers need to be aware of the diversity represented, all of which can inspire better learning. It sometimes adds uniqueness for a course when the teacher asks students to consider why specific problems and issues are included. Who thinks that the topics comprising labs and lectures are perceived as important? Too often students are not part of the leadership; they often do not see themselves as more than recipients of what teachers expect them to do themselves!

No Lectures

A successful college teacher needs to be willing to appreciate that lectures represent teacher actions from which little real learning results. This monograph includes many ideas and suggestions of why and how faculty procedures are sure to be unsuccessful when lectures are expected and offered as the main focus for teaching.

It is important for teachers to ask what the goal is for a given course. Too often this is not even considered. In fact in many high schools, courses are structured around specific concepts just because it is assumed that it is just what they are expected to do! Too often college teaching does not include student participation, interactions, and experiences. Again, the major focus should be on student learning. Too often the lecture method is what is expected by the department head or by the university leaders as a whole. Too many faculty members from research universities are quick to indicate that they are primarily interested in their own research, publications, and success as being more important than teaching a course. Teaching is something they are expected to do—to share their understandings with students. The quick and easy way is to prepare a lecture, probably like the ones they experienced as students themselves. Most are not willing to admit that their own learning did not come from a lecture. Many never give it a further thought. They rarely see teaching as a major effort related to their role as a professor. It is rare for the most successful students to be able to do more than to repeat what they "learned" with the same explanations and visions that were used by the professor. Again, such teaching is an act of transmission! Few science professors have ever had a pedagogy course or even heard of constructivist learning theory. A reform of college teaching is needed to attract more students to careers, to develop better citizens, and to find desired employment.

Technological Aids

Current society sees advantages of technological advances for education. One can use technology to enhance typical teaching (i.e., continuing to encourage students to accept the explanations that accumulate from the work of scientists). Technology is often not understood nor in any way controlled. But it often is used as related to lectures (and associated labs). It often characterizes and relates to structured curricula. Sometimes college teachers are forced to use lecturing to handle larger numbers of students or to get specific information to illustrate industries associated and found at other locations and environments.

Some of the uses of technology are tied to educational technology. Some of our reviewers were critical and questioning about technology as examples of what is appropriate for exemplary teaching. The nice part of technology is the engagement of students in planning and using it as a tool for learning. Most of the examples and improvements have only loose ties to a given community. It is also of little use to merely use technology to supplement the science lectures and cookbook labs.

The current reforms often include emphasizing technology (the T of STEM), which is critical as we redefine content and teaching goals for all K–16 grades. It would be interesting to see where STEM efforts in all states produce changes that relate to improving the teaching outcomes that most reforms seek to produce.

Science Begins With Problems: Whose Problems? Society, Scientists, or Students?

Few college science classrooms start with student questions or issues. How does this affect college teaching, not focusing on students, their experiences, ideas, and needs? Too few see ways to change teachers who teach major parts of their own major discipline area. Too seldom do college teachers start as scientists, separating "doing" science from merely choosing facets of "agreed upon" content included in textbooks.

Most standardized test providers (who are central to college science teaching) do not claim to know the meaning of science, or how it should be used in teaching. Testing experts prefer to perceive what teachers teach as enough and all they need to do to prepare test material to match what occurs in *their* classrooms and laboratories. Tests should reflect real learning by students, not merely what they remember.

Reforms are difficult! But, it is important to realize that learning is an individual experience. Sometimes the best learning occurs from errors. Scientists need to analyze their science experiences and what research unveils about learning. Everyone (including technology experts) need to then prepare exams that focus on improved learning for students, for colleges, and for themselves. Sometimes this will involve actual use of the ideas and skills in a new context. Some call for more teacher education for college science faculty, saying that college science teachers must know science for their science careers (including a special line of research). This too often ignores the needed role for exemplary teaching!

Service Learning

One of the chapters (chapter 14) deals with service learning. While not something that all should do, service learning offers important possibilities. Questions can be resolved, community members can become involved, and changes can be made. Of importance is how improved teaching is related to all levels of high school and college teaching of science.

The important aspect is whether all students are involved and if all the needed "services" can revise teaching that places the teacher as part of societal improvement. The advantages include a way of meeting some of the other aspects of current reform efforts. These include defining a problem, community involvement, including all the STEM areas, with actual results in teaching STEM and the needed associated research. Such efforts illustrate the power and effort gained by collaboration among teachers, students, and others in a given community.

One could argue, however, that service learning would be a way to illustrate real teaching improvement as a definition while also helping decide what information should be available for student work. It is also a way to assess teacher experiences while also ridding science of merely recasting what fairly typical science has unfortunately accomplished.

College science instructors often find it hard to relate to what the National Science Education Standards for K–12 teaching advocates. Too often students never know how science is practiced. Service learning provides new parameters for changing thinking and the ways students are introduced to it. It promotes a vehicle and replacement of the course lectures and associated labs. Again, these teachers choose what are often not found as meeting student needs and interests. It is hard to use constructivist theory when a college teacher has never experienced it him- or herself.

Changing Teaching Versus More of the Same

Change is difficult! But, change is always necessary if real reforms are to occur. These chapters provide important ideas and results to promote science and specific changes for many who see the light; but, how to encourage more change? This is the primary purpose of the NSTA ESP effort.

It was Paul Brandwein who often spoke of how to get more involved with the reforms and how to get their experiences shared and accomplished to advance the rest of society. We hope that all the authors involved with the college teaching monograph will continue to use, change, and encourage others to share ideas. It is like becoming a scientist in an education situation. Again, this means starting with a problem, preparing possible solutions, gathering evidence that it works, considering what others have done to keep learning continuous. We look forward to publicizing the successes and "spreading the word." This is considered the major focus for this monograph.

We hope to remain in touch as more changes are tried to offer new successes that are experienced. We continue to analyze the debates. It is hard to imagine what will happen as new students are taught using the ways envisioned. Maybe new features of constructivist theory will be more central in changing teaching in colleges. We hope the new features of teaching are more successful with greater learning results and speed up the process.

Science Is Basic for Learning in General

With successful science teaching, it is easy to see ties to journalism, all the successful STEM features (especially with respect to mathematics), art, and the humanities. All associated issues for improving education are enhanced by science; activities and real science experiences in colleges should be available (Saul et al. 2012). The current reform movement centers on major changes as set forth with the science as contained in textbooks and curricular frameworks. It is instead something where the successful educators want changed perspectives and use of constructive theory, just as important theories influence science.

There is evidence that every student can be involved using his or her own experiences with science. This does not mean all need to do the same things—learning occurs ideally when experienced in diverse ways. There is no quick fix when teachers change their teaching strategies. The change should focus on each one involved with experiments in teaching (i.e., learning in constructivist ways, which means that teachers become more engaged). Learning is then seen as more successful, and science itself is seen as more interesting, meaningful, and useful. Many students never accept science as more than encouragement to take the next course for a college major. Why is the encouragement needed to inspire and encourage more for college science teaching? Change in college teaching is what is needed to improve life as we know it. The reforms described in this monograph illustrate what can be done.

The Power of Differences Among Students

Many teachers set up barriers for learning when starting with their basic plans, textbooks, and their own personal interests. Too often students are caught up in doing what their teachers expect of them. Student creativity is something students experience; it is natural—but too often it is not valued or encouraged in educational settings. Student-centeredness is something most will subscribe to, but not something nurtured or used to interest students. Too many ignore students, especially in classes enrolling 50–500 students. Students are all different, but too often their differences are not used to promote learning. Nor is student-centeredness practiced as a way of inviting teams of students to work on individual or group projects. If reforms are desired, they must be original and conceived by students—not merely something students volunteer to do and to conceive as their own. The focus on proposed projects should come from groups of students, not teacher lesson plans. Students can be more successful later in encouraging other students to be involved if they experience such teaching themselves. Changes should mirror work in communities among various groups comprising a society.

Focus on Learning Versus Teaching

College teaching should be concerned first of all with student learning and not what college faculty members find interesting or what they are particularly knowledgeable about when they work with assigned learners. But, typical science teaching in college environments too often ignores student interests and past experiences. Students are supposed to absorb what teachers present to others to earn grades, indicating success in most college courses. Typical science teaching should be sharing a common "story." It should be a reflection of what each student becomes. It should be related to their work as students and include their own research. Effective teaching means being personal and enthusiastic!

Teaching rarely veers from what has been "common," with the generally accepted view that it is the teacher's course to plan and carry out. Students too often are but "recipients." If science teachers can allow students to "do" science, there will be more learning, more positive student attitudes, and more connections to a community of learners and citizens in general.

Unfortunately teaching is not considered as something to test. Instead, most college courses tend to be structured to provide specific information and skills for students to "learn," with the end result that they merely memorize concepts. If education is an activity that can be studied and improved, we will have a revolution concerning real learning—especially where one is caused by college science faculty.

The 16 stories in this monograph are all fine examples of how college teaching must change if stated objectives and experiences are to result in successful learning. Readers are encouraged to read and react to each concerning their own teaching efforts. There are likely great differences and some similarities. This set of examples and the ESP monograph are offered to encourage more analyses and current experimental efforts concerning exemplary college teaching. They represent well what STEM efforts are designed to promote!

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Robert E. Yager—an active contributor to the development of the National Science Education Standards—has devoted his life to teaching, writing, and advocating on behalf of science education worldwide. Having started his career as a high school science teacher, he has been a professor of science education at the University of Iowa since 1956. He has also served as president of seven national organizations, including NSTA, and has been involved in teacher education in Japan, Korea, Taiwan, Indonesia, Turkey, Egypt, and several European countries. Among his many publications are several NSTA books, including *Focus on Excellence* and two issues of *What Research Says to the Science Teacher.* He has written more than 700 research and policy publications as well as having served as editor for eight volumes of NSTA's Exemplary Science Programs (ESP). Yager earned a bachelor's degree in biology from the University of Northern Iowa and master's and doctoral degrees in plant physiology from the University of Iowa.

Students Teaching Students: Jigsawing Through an Environmental Biology Course

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Setting

The environmental biology course discussed in this chapter was designed for non-science majors, most of whom were preservice elementary education students. The course was taught by faculty of the biology department at Indiana University of Pennsylvania, and follows the recent recommendations put forth by the American Association for the Advancement of Science (AAAS), the National Research Council (NRC) and the National Science Teachers Association (NSTA). Instruction in the course is designed around the constructivist teaching model based on inquiry instruction and features the student-teaching-student design of instruction.

Students have been evaluated on their learning in science courses for decades. The most favored method of gauging learning is through instructor-generated exams that are aimed at what the class members can recall from their readings and lecture materials. Assessing what students can recall from the professor's presentations generally measures the facts, definitions, and terms recalled from class and not to what the test takers can apply or relate to they have not heard in the class. For this to occur, it's believed students need to take a larger role in their learning; and this has led educational leaders to propose involving students more actively in the lesson rather than treating them as passive spectators (Knight and Wood 2005; Walker et al. 2008; Wood 2009).

To discover how to engage class members more in their learning, the American Association for the Advancement of Science (AAAS) invited a number of college science instructors, recognized as leaders and innovators in the field, to a weeklong meeting to discuss how this could be accomplished. Also invited to attend the sessions were college biology student-leaders whose input was sought by the organizers in order to get the learners' prospective. The attendees not only examined what was being covered in the science courses generally taught during the typical eight semesters of education, but how the professors were teaching the subject matter to the students. To enable this huge task to be accomplished in the short time provided during the week, the leaders decided to direct their efforts to instruction in the life sciences.

Teaching Through Inquiry Instruction

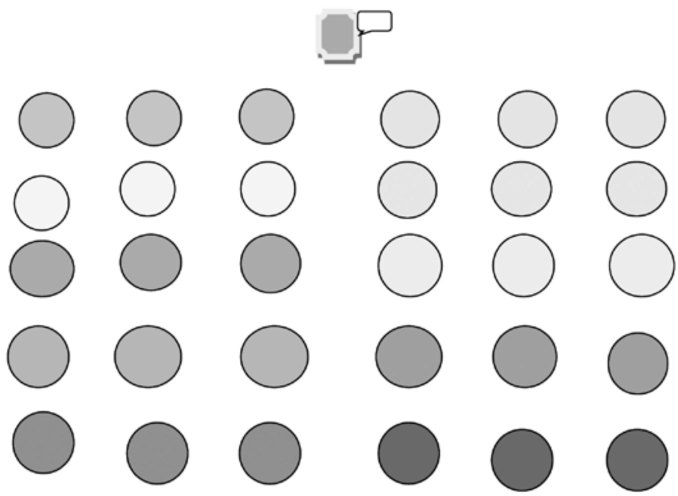
The participants also discussed several innovative instructional methods that had been shown to be effective with young adults. The most frequently talked about strategy discussed by the conference participants was the innovative use of inquiry in the learning process. Inquiry instruction involves experiencing content through questions that students attempt to answer by sharing and discussing their thinking with teammates. Contemporary learning theorists believe that as team members consider the suggestions and responses of their partners for the challenges, they blend the new information with their preconceived understandings about the topic and build new knowledge for themselves (Fuller 2002). One of the major components of the inquiry model, therefore, is that students can effectively learn course content from each other. The role of the professor in the inquiry strategy shifts from being the presenter of content to be learned by students to being the manager of a student's learning the content (Fosnot 1996; Gafney and Varma-Nelson 2007).

A good example of how inquiry works in biology is in the instruction of cell structure and function to introductory life science students. Traditionally, class members are taught the various components of the cell via the instructor pointing to a drawing of each cellular element on an overhead transparency or a PowerPoint slide and describing its makeup and function. As the instructor goes over the cell membrane in this traditional way, for example, class members quickly sketch the structure in their notebooks and jot down its various components. In the meantime, the professor has likely moved on to a description of passive and active diffusion and various structures within the membrane itself.

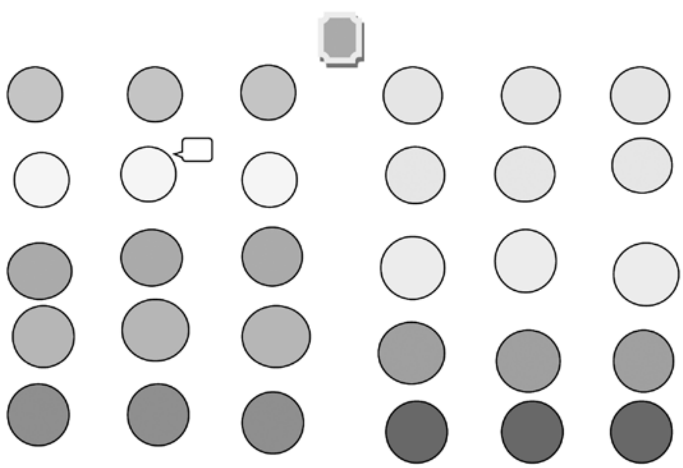
An inquiry instructor, on the other hand, would likely follow the 5E Instructional Model (Bybee 1997) by introducing the lesson with a discrepant event, attention-grabbing reading, a short demonstration, or a video clip on diffusion. The instructor could, for example, pass around several inflated balloons, each containing the concentrate of a different spice (e.g., cinnamon or vanilla) and then ask students in the class to describe the smell of each balloon. Known as an *engage*, the event sets up the topic of the lesson for the students. Class members, working in teams of 3–5, are next challenged to come up with (*explore*) 10 factors that would influence the movement through the membrane of the molecules just sensed. Jotting down their answers on a sheet of paper, teams are given several minutes to come up with their ideas before their answer sheet is collected. Once all the answers are retrieved, the instructor randomly selects a response and asks one of the writers of the sheet to share the team's ideas with the rest of the class (*explain*). When the shared answer is completed and verified, the professor randomly chooses a second paper from the stack and asks a member of that group to share one of that team's answers. The procedure is continued as students from various teams share (or teach) their answers to their classmates. Eventually the instructor displays all the potential answers on the PowerPoint screen to round out the discussion (*elaborate*; the final "E" is *evaluate*). In the inquiry model, when students teach and learn from other students in such a manner, the strategy is known as a jigsaw (Figure 11.1).

Figure 11.1. Schematic of a Jigsaw for a Challenge Question Asked to the Teams by the Instructor and a Response Given by One of a Team's Members

In this jigsaw method, students in small teams discuss a challenge question posed by the instructor and together, come to a consensus on the issue (each team is challenged to answer the same question). To hold them accountable, the teams jot down their answers on a sheet of paper and give it to the instructor.



Once the instructor obtains all the teams' responses, one of the group's answer sheets is drawn from the stack by the professor, who asks one of the members on the team who created the sheet to share their answer with the rest of the class. The student sharing routine is continued until completed.

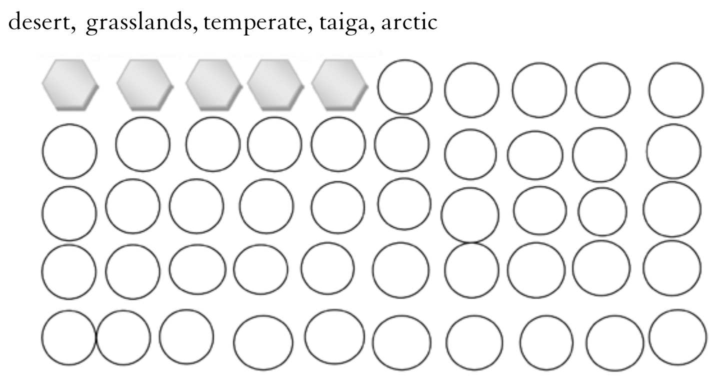


Working Models of Jigsaw

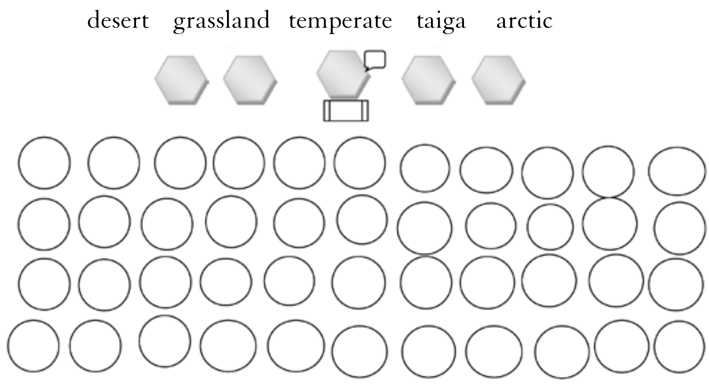
There are several teaching techniques that employ alternative jigsaw models. In my environmental biology class, student teams of three to four members select a course issue from a series of topics on the first day of class that they will research. To help guide the researching groups, each issue contains a list of items that team members must include in their presentation. For example, a team that selects the topic *environmental succession* is required to include the various biotic and abiotic characteristics of each successional phase in their report. Team members of this topic refine their teaching of the topic by taking one the serial phases of succession as they research the characteristics of that one phase. One participant, for example, would research the characteristics of pond succession, while a partner team member would investigate the succession of marshes; the pattern is continued as a third team participant researches the development of an old field, and a fourth member of the team examines the succession of a young forest to its climax. Many times, the student group with this topic will choose to teach the class what they have researched with short PowerPoint presentations of 10–15 minutes (Figure 11.2).

Figure 11.2. Jigsaw With Group Presentations.

In this jigsaw method, each team selects one of the topics in environmental biology to present to their colleagues in the class. The presenting team members research their topics, collect graphics to support their talk, and prepare PowerPoint slides for the presentation.



On the day of the presentation, presenters stand behind a podium and share on the PowerPoint slides the information they discovered through the research in 10-minute snippets. Students in the class may ask questions or inject topical comments throughout the presentation.



Besides presenting information to the class in my environmental biology course, I require teams to produce a multichapter term paper on what the group has discovered. Each member of the team is responsible for one chapter of the document that includes what he or she has researched and presented. To assure that chapters are proportionally the same length, students are told they cannot submit a chapter shorter than four or longer than five pages. The creators of the term paper will be given two grades for their efforts, one for the chapter they have written and a second grade for the overall composition of the document. Members are encouraged to proofread the entire document (his or her own and other teammates' writing) for spelling, punctuation, and grammatical errors.

The jigsaw technique can be used just as effectively with small clusters of students instead of groups (clusters are nonpresenting members in the class that have been divided into four or six groups). In the environmental biology class, I initially follow a similar format to the one above. I divide teams into clusters of five students and present them with a topic of which each member in each team is responsible for a different aspect. In a class studying North American biomes, for example, group members are required to include the characteristic flora and fauna, along with several important abiotic factors, of each biome region (deserts, temperate forests, grasslands, taiga, and arctic). Team members are also encouraged to find photographs, maps, and other graphics of their selected biome to share with the groups they are teaching. Team members are told they are required to complete their presentation in a 10-minute period so as to not interfere with a teammate's presentation that will take place immediately following his or her talk. In this example in environmental biology, teams are composed of five members, each with a different biome to share. On the day of the presentation, each researcher presents to class members in his or her cluster what they have found out about their biome. As long as the 10-minute time allotment is followed during each rotation from cluster to cluster, the entire class will have learned the information about a biome from the five presenters (Figure 11.3, p. 150). As in the previous example, the term paper required by the group would contain four to five chapters, each contributed by one member of the team.

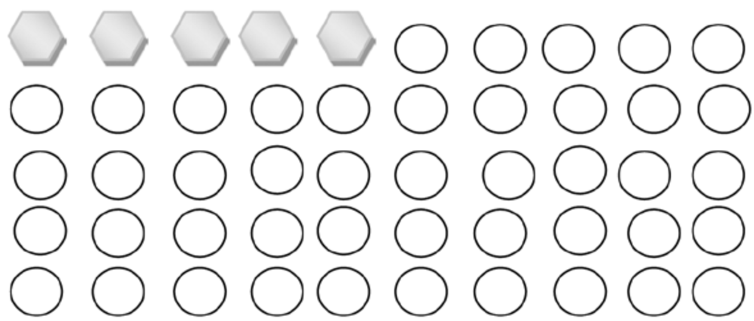
I use jigsaw instruction with my environmental biology class in other ways. Instead of assigning various members of a group to research a different biome, I've assigned all the members of a team to research all aspects of the same biome. To make the jigsaw work, I assign the members of a second team in the class to research the characteristics of a second North American biome; students in a third team are assigned to investigate a third biome, students on a fourth team are assigned to explore a fourth biome, and members of a fifth team are assigned to research the fifth biome. In this technique, since members on a single team will research the same biome, they must each select a different characteristic of their biome to write about in their term paper.

On the day of the presentation, one member from each of the five researching teams will join one member from each of the other teams. This brings together one individual in each team who has researched a particular biome. The five researchers at each cluster is then given 10 minutes to present what he or she has learned about his or her particular biome (Figure 11.4, p. 151).

Another way that I use the jigsaw technique in environmental biology class is to employ the debate technique often used in traditional classes. In the jigsaw model of the debate strategy, two teams of three or four students are asked to choose either to support or contest a contemporary issue. One of the topics that go well with the debate strategy is climate change. Members of one team research their side of the topic and organize a plan to use in a classroom debate against a second team who has investigated the alternate side to the topic. Research papers produced by each team consist of three to four chapters, each written by one member of the team. The topics of each chapter must be different and be supported by scientific documentation. For example, teams arguing that climate change will not be as devastating as many believe must back their stance with reliable evidence. This group, for instance, could show evidence that Earth's warming could open waterways through the Arctic, which will be good for commerce and trade. The opposing team would likely counter that opening the ice sheet in the arctic will likely lead to the extinction of the polar bear. On the day of the debate the two groups will be

Figure 11.3. Jigsaw Schematic of a Team of Five Members Presenting Different Aspects of a Specific Topic to Their Classmates

After all the groups have selected a topic, each team member on one of the teams researches a particular segment of the topic to present to their classmates.



On the day of their presentation, one member from the team will join a cluster of their classmates and present what they have discovered about the topic. After 10 minutes, the presenter will move to the next cluster of classmates and repeat the presentation to the second group. This routine is repeated until the whole class has heard the presentation.

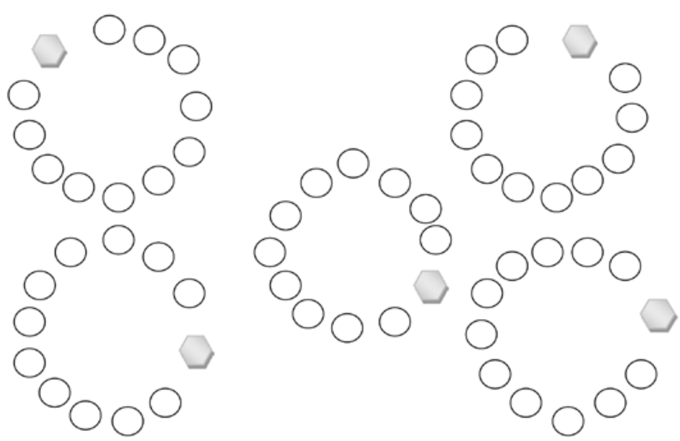
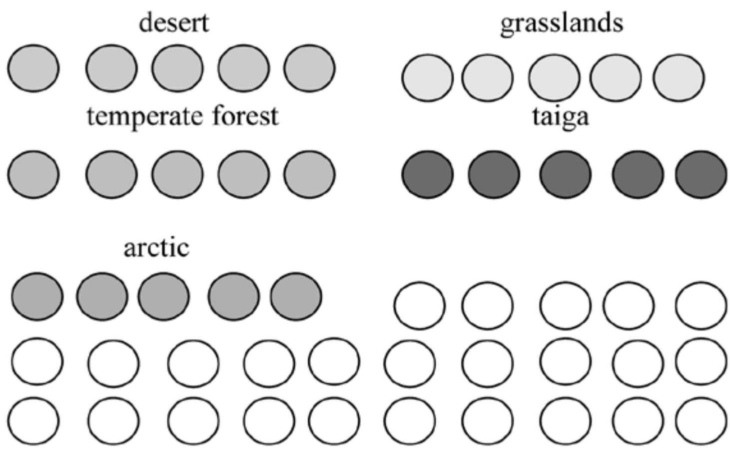
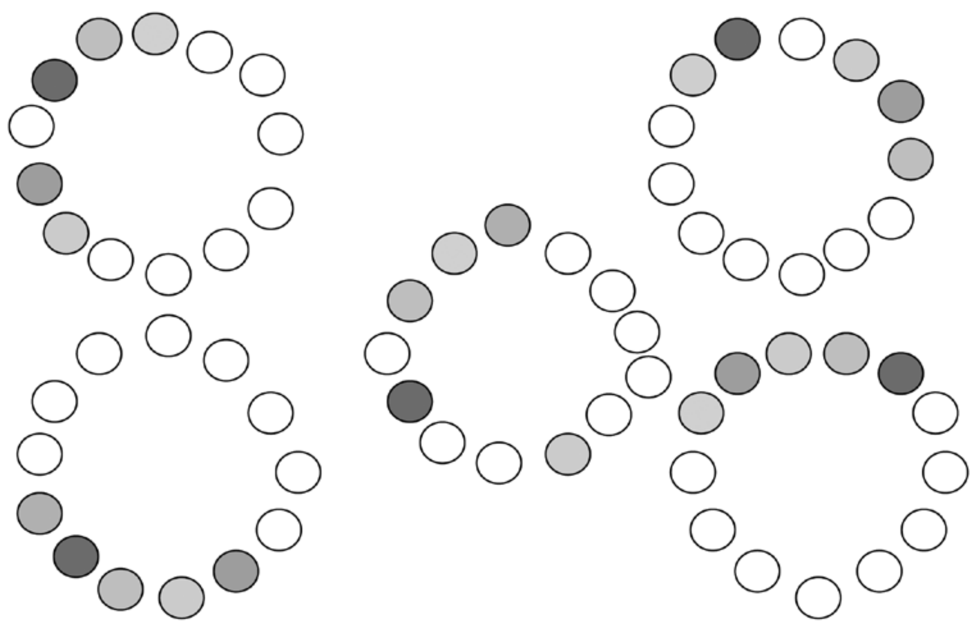


Figure 11.4. Jigsaw Schematic of Five-Member Teams; All Members of a Team Learn a Specific Aspect of a Topic to Share With Their Classmates

After all the groups have selected a topic of the course, each team member on one of the teams researches a particular segment of the topic to present to their classmates.



On the day of their presentation, one member from the team will join a cluster of their classmates and present what they have discovered about the topic from their research. After 10 minutes, the presenter will move to the next cluster of classmates and repeat what they research to the second group. This routine is repeated a third, fourth and fifth time until the whole class has heard the topic.



seated on one side or the other in front of the class. The teams will have equal time to present their side and to question each other. The course instructor will moderate the debate. At the conclusion of the class, the audience will select the winning team, justifying their decision with supportive reasons (Figure 11.5).

The debate format can be modified into a small-group format instead of the large group. Teams of two or three students work together to present in a "discourse" fashion the conflicting issues pertinent to topics in environmental biology (e.g., pros and cons of using biofuels on the growth and development of living things). The student group is then matched against two or three additional classmates who have researched the opposing stance on the same issue (Figure 11.6, p. 154). When the class meets for the discourse session on the topic, each student presents his or her side of the issue to a cluster of classmates. Halfway through the period, the presenting students move to a cluster that has not learned about that side of the issue, and present their side of the issue a second time. At the end of the class hour, every class member has learned both sides of the issue. Working with their discourse peers, the clustered students assess the quality of the pro and con presentations. This instructional method empowers students in the cluster to share feelings about the issues and reveal why they think one presenter did a better job than the other.

The final use of the jigsaw model used in my environmental biology course is what most often is thought of as learning through practical examples. Recommended for implementation for longer laboratory periods, this teaching scheme involves small groups of students researching separate course techniques and teaching what they've learned to their peers in the class. When, for example, the class is learning about air pollution control systems, five members of each team research the control procedures of just one of five categories of noxious pollutants (acids, gases, mercury, nitric oxides particulates, and volatile organic compounds). On the day the topic is discussed, one member of each team joins with one member of each of the other teams and the new group moves from one demonstration site in the room to another in an orderly fashion. When the group arrives at each site, the student who is knowledgeable about the process at that location teaches his companions about the cleansing procedure setup at that location. By moving to each station every 20–25 minutes, the entire group learns about the cleanup of a noxious pollutant at each site. This results in an understanding of pollution control by the entire class (Figure 11.7, p. 155).

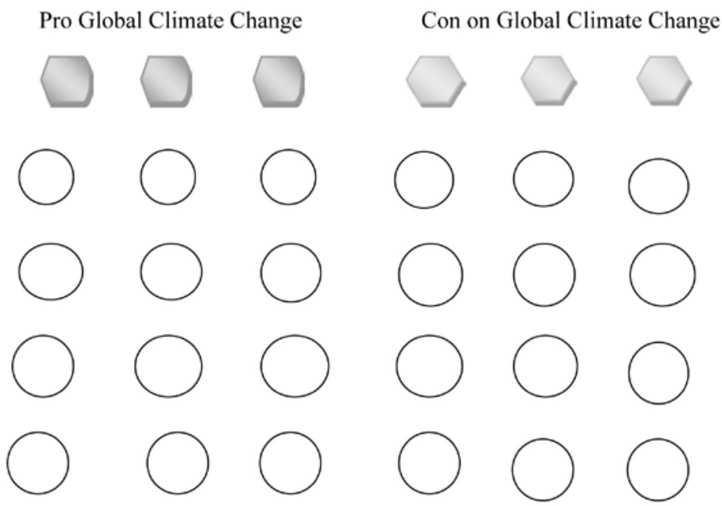
Student Thoughts and Comments on Jigsawing

Overall, class members in the environmental biology class reacted positively to the student-teaching-student methods. Initially, the biggest concern class members taught by the various jigsaw methods have is whether they will learn the same level of content as they would if the professor taught them the lesson. This apprehension occurs despite research that has found the students learn as much, and in some cases more, when they teach one another (Cross 1990; Fuller 2002; Wood 2009). The anxiety can be further reduced when the class members realize that each presenting student is provided with a list of items they are required to include in their presentations and, further, that the student presenters go over their lesson with the professor before their talks. Typical comments are (text continued on p. 156):

- I like learning from other students because they explain things in a language I understand.

Figure 11.5. Jigsaw Schematic of the Student-Teaching-Student Debate Format

In this jigsaw method, two groups of three or four members select opposing stances of a contemporary issue. The members of each team research articles, texts, or documents to support their stance on the issue.



On the day of the debate, the participants arrange themselves in seats on either side of the classroom in front of their classmates. The moderator (course instructor) sits between the two groups and asks questions.

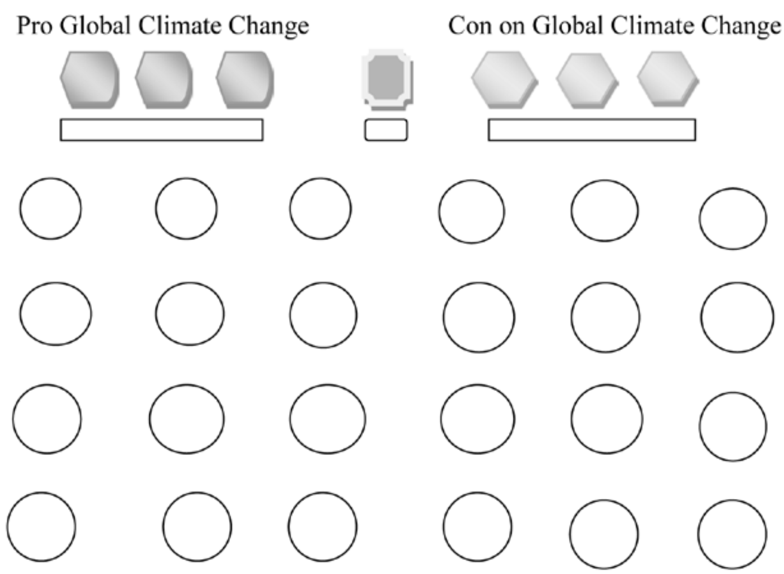
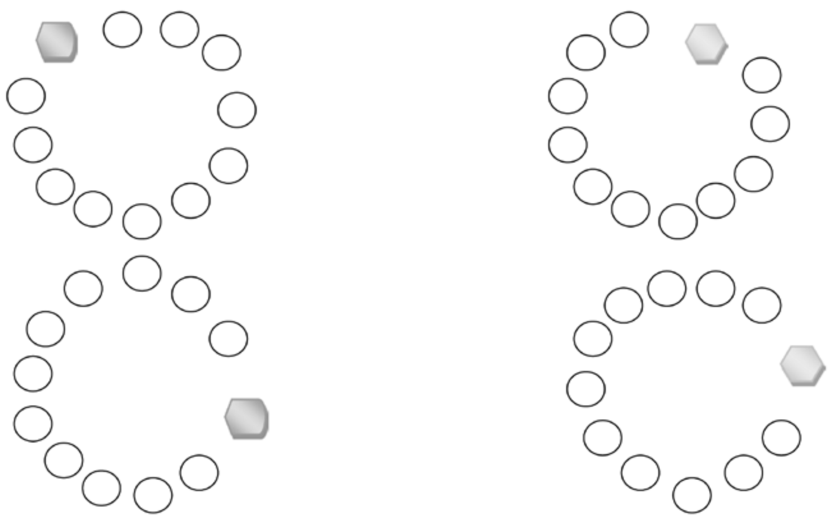


Figure 11.6. Jigsaw Schematic of a Discourse Between Two 2-Member Teams

The diagram below represent two teams, one that selected to research the favorable side of an issue (e.g., pro pesticide usage) and the other team selected to research the opposing side of the issue (con pesticide usage).

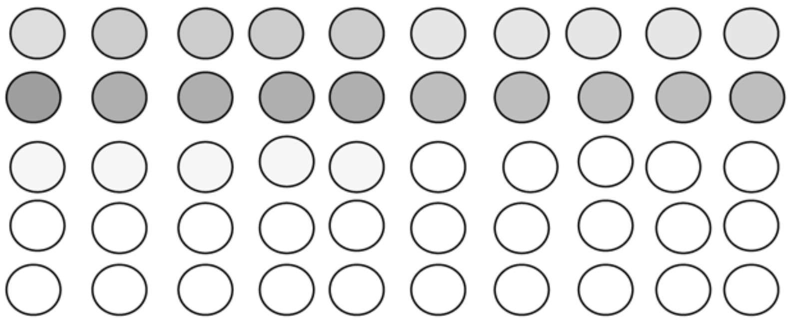
Each team researches their stance on the issue (together or separately), meeting periodically to share what they have discovered and to design graphic support items. On the day their issue will be presented, the two team members on each issue have identical documents to present to their classmates.



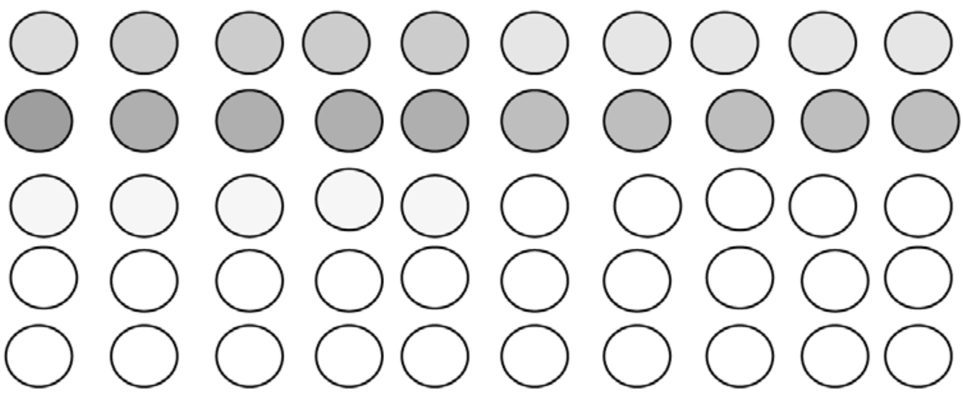
After 20–25 minutes, the instructor terminates the discussion and switches the presenters to a cluster that has not heard the other side of the issue. The presenters repeat their presentation to the second cluster. After a second time period of 20–25 minutes, the instructor closes the discussion and directs the four presenters to leave the room for 5 minutes.

Figure 11.7. Jigsaw Schematic of Teams of Five Members, All Learning Through Hands-On Course Techniques

After all the groups have selected a pollution clean-up strategy, all the members of each team research that technique and teach it to the members of other teams.



On the day of their presentation, one member from each team will join a cluster that is not represented by a knowledgeable person and talk about what he or she has researched. After 10 minutes, the teaching students will move to the next cluster of classmates and repeat what they researched to the second group. This routine is repeated a third, fourth, and fifth time.



- I find it's less intimidating being taught by our friends than from the professor.
- When I learn from a friend the atmosphere in the class is more relaxed and fun.
- I am more likely to ask a question or share a concern with others when being taught by my friends in a small cluster instead of a professor in a large lecture hall.

One student even remarked, "I've always hated science and never learned anything from the science classes I've taken; however after taking environmental biology, I realize how interesting and fun science can be."

There are some students, however, who dislike the student-teaching-student scheme of learning. Opposing comments included:

- I learn better when the professor tells us in his own words what we should learn.
- I like being taught more from the professor when I can sit back and learn the way I'm use to.
- The jigsaw method seems more appropriate for high school students than college classes.

However, not only do most students enjoy teaching and learning from each other but studies show that they learn as much or more than they do from instructor-dominated classes. Research (e.g., Angelo and Cross 1993; Cross 1990; Huba and Freed 2000) has found that students taught through student-centered inquiry score higher on their exams and retain the information longer than students in non-hands-on classes. In a study by Handelsman and colleagues (2007) it was found that enhanced student activity heightens the thinking levels of the participants and leads to greater understanding and recall of what is being taught. Additionally, research by Ebert-May and colleagues (2003) concluded that students actively involved in the teaching and learning of their courses demonstrated significantly higher proficiency in the courses they were taking than students in traditional lecture courses. The findings of the students teaching each other in environmental biology support these report results. The overall majority of students in the environmental science course said they would like to take another science course taught through inquiry.

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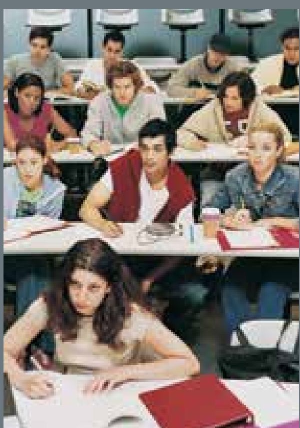

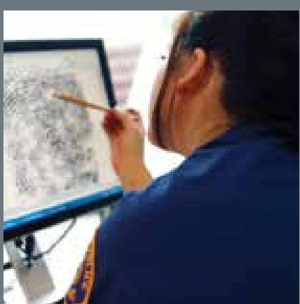

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