Reaching All Students

A Resource for Teaching in Science, Technology, Engineering & Mathematics

Second Edition

Sherrill L. Sellers
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Katherine Friedrich
Caroline Hammargren

CIRTL

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Center for the Integration of Research, Teaching, and Learning
Madison, Wisconsin

Reaching All Students is a resource developed by the Diversity Team of the Center for the Integration of Research, Teaching, and Learning (CIRTL), a NSF-funded multi-institutional project of the University of Wisconsin–Madison, Michigan State University, The Pennsylvania State University, the University of Colorado at Boulder, Howard University, Texas A&M University, and Vanderbilt University. During the Diversity Institute in 2004-2005, diversity scholars recruited from across the nation collaborated with the CIRTL Diversity Team to explore inclusive teaching in post-secondary science, technology, engineering, and mathematics. Resources currently available include:

Reaching All Students: A Resource for Teaching in Science, Technology, Engineering & Mathematics
Case Studies in Inclusive Teaching in Science, Technology, Engineering and Mathematics
Literature Review
Web Links Directory
Content Matters: An Inclusive Syllabi Project

For more information on these and other resources, visit
http://cirtl.net/diversityresources/

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Diversity Institute

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What are the issues?

"I think most of us assume… that the students out in the classroom are the same as we are."

– Judith Burstyn, Professor of Chemistry and Pharmacology, University of Wisconsin-Madison

"My experience is that… most people will say they don't have a problem."

– Jim Stith, Vice President-Physics Resources, American Institute of Physics

"I've been becoming more and more concerned that there is a deficit of students from diverse cultural backgrounds."

– Erica Howard, Ph.D. graduate, Nelson Institute for Environmental Studies, University of Wisconsin-Madison

"[Teachers] just don't know where to start."

– Wayne Jacobson, Associate Director, Center for Instructional Development and Research, University of Washington

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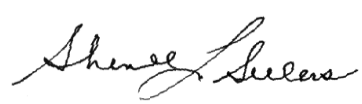
Foreword

Nationally, the scarcity of American students interested in going into STEM fields (science, technology, engineering and mathematics) is a cause for concern. Women and minority students could help make up this deficit – but only if they are welcomed. Numerous studies have documented the existence of a "chilly" interpersonal climate in STEM fields (see the CIRTL Diversity Resources Literature Review for specific references), but studies also show that in classrooms where students are working together well, women and minority students feel more at home. Welcoming all students into STEM disciplines is the goal of the resource book, *Reaching All Students*.

Reaching All Students includes a selection of published materials from universities across the country, modified to be appropriate for STEM, and original articles written specifically for CIRTL. The process of developing this resource reflects the three pillars of CIRTL: Teaching-as-Research, Learning Communities, and Learning-through-Diversity. The Diversity Team formed a learning community to examine existing resources on teaching; developed a research protocol for assessing these sources; and infused information on diversity throughout the process. The volume speaks to their perseverance and commitment to the goal of providing STEM-focused teaching resources that present diversity as integral to teaching excellence.

Teaching is hard work. Yet I believe there are few more exciting challenges than to teach. Each class period is an opportunity to shape the future, for the students you teach will lead the next generation of research and scholarship in STEM.



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Using This Resource

Our goals in compiling this resource book were to provide instructors with tools for teaching and to weave diversity throughout the volume. Although many of the documents that we examined were well-written, most were written for college instructors in general and were not STEM-specific. Further, few of those resource books incorporated diversity fully.

It is possible that a good portion of the difficulty with truly creating inclusive learning environments is that we do not see inclusiveness modeled. Instead, diversity is presented as an add-on and, therefore, is often ignored.

This resource book attempts to weave diversity through the life of a course – from planning the class, to choosing teaching methods, to end-of-semester evaluation of oneself and assessment of student performance.

This resource book attempts to weave diversity through the life of a course.

We do not intend for *Reaching All Students* to be a comprehensive teacher-training manual. Instead, we hope to pique your interest and demonstrate how to integrate diversity throughout a STEM course. We intend the resource book to become a reference not only for future faculty in STEM, but also for current faculty.

"Part One: Preparing to Teach" discusses how to plan and develop a course by choosing objectives and selecting teaching strategies. It offers information on how to get to know your students and how to create a learning environment that will reach students of all different backgrounds. In addition, there are ideas on developing a syllabus and tips on general teaching skills, including how to think about communication.

"Part Two: Teaching Methods" is the heart of the volume. Beginning with the first day of class, this section offers suggestions on how to engage students with a variety of teaching methods, encouraging faculty and future faculty to experiment with various teaching approaches. We present the strengths and limitations of different teaching methods, along with reference lists to help the reader explore the topics further. We discuss instructional methodologies including lecturing, discussions, group work, science labs and alternative teaching methods. This section also contains articles on how to effectively use case studies, how to select terminology to use with students, and how to deal with disruptive behavior.

"Part Three: Teaching-as-Research: Continually Improving Your Teaching" addresses assessment and evaluation issues for instructors and students. End-of-semester evaluations are necessary, but are only a small part of the process of improving one's teaching skills. The section is intended to stimulate creative thinking about how to smoothly incorporate evaluation, an important dimension of the CIRTL principle of teaching-as-research, into courses and how to find different methods to improve your own teaching.

<u>"Part Four: Appendices"</u> begins with five inspirational essays by UC-Berkeley teaching assistants on inclusive teaching, as well as an engaging article by a faculty member reflecting on his many years of teaching experience. It also includes a list of additional resources and websites that address diversity in STEM education. The CIRTL Diversity Team staff have reviewed all of these resources. The appendices also offer a recommended outline of a TA Handbook.

The original sources of the information in *Reaching All Students* are listed in the endnotes. Most of the pieces have been adapted by the CIRTL team, infused with inclusive teaching practices, and made STEM-relevant. All source references are listed in the Works Cited section at the end of the book.

The Center for the Integration of Research, Teaching, and Learning

The mission of the *Center for the Integration of Research, Teaching, and Learning (CIRTL)* is to develop a national faculty in science, technology, engineering and mathematics (STEM) committed to implementing and advancing effective teaching practices for diverse student audiences as part of their professional careers. Such a faculty will enhance the learning of all students, and thereby increase the scientific literacy and technical engagement of the nation.

CIRTL is a National Science Foundation Center for Learning and Teaching. Today, in 2007, the CIRTL Network consists of the University of Colorado at Boulder, Howard University, Michigan State University, The Pennsylvania State University, Texas A&M University, Vanderbilt University, and the University of Wisconsin – Madison.

Three core ideas, or pillars, provide the conceptual framework for all that CIRTL does:

- **Teaching-as-Research** is the deliberate, systematic and reflective use of research methods by STEM instructors to develop and implement teaching practices that advance the learning experiences and learning outcomes of all students.
- **Learning Communities** bring together groups of people for shared learning, discovery and generation of knowledge. To achieve common learning goals, a learning community nurtures functional relationships among its members.
- **Learning-through-Diversity** capitalizes on the array of experiences, backgrounds and skills among STEM undergraduates and faculty to enhance the learning of all.

Combined, these pillars provide a faculty member with the foundation for a dynamic, progressive and collaborative approach to guiding student learning throughout his or her career.

The national goal of enhancing the diversity of people engaged in STEM requires a higher education faculty that can promote the success of everyone as the student population becomes increasingly diverse. While some see this as a challenge, CIRTL sees this as an opportunity. Excellence and diversity are necessarily intertwined, and **CIRTL seeks to promote teaching skills that use the rich diversity of students and faculty to benefit all**. That is, CIRTL seeks to promote Learning-through-Diversity in college classrooms across the nation.

At the same time, CIRTL recognizes the reality that existing social and educational practices do not always promote equal success for all learners. Thus, creating equitable learning experiences and environments requires intentional and deliberate efforts by present and future faculty. **CIRTL seeks to develop faculty who model and promote the equitable and respectful teaching and learning environments** necessary for the success of Learning-through-Diversity.

To achieve these two goals, CIRTL provides development experiences, programs and resources that develop in STEM faculty the skills to:

- **Know the diverse backgrounds** of students and the resulting implications for learning. Dimensions of diversity include, but are not limited to, preferred learning style, race, ethnicity and culture, gender, sexual orientation, disability, religion, age and socioeconomic background.
- **Recognize existing inequities,** and promote an equitable, inclusive and respectful climate for learning.
- **Identify curricular, teaching and assessment practices** that promote learning for all.
- **Draw upon the diversity of students** to enhance and enrich the learning of all.

Importantly, STEM faculty must be able to apply these skills across multiple dimensions of the teaching and learning experience, such as:

- **Student-teacher interactions** - such as inclusion and engagement of the ideas of all participants; respectful teaching behaviors; accessibility for all participants; and mentoring of less experienced practitioners.
- **Student-student interactions** - such as welcoming and respectful inclusion in collaborative work; respect for the ideas of all and recognition of their value; and accessibility in activities that occur outside of the primary learning environment.
- **Student-content interactions** - such as how participants experience content; how content can be adapted and varied; and how exploring novel contexts for presentation can enrich the experience of participants and practitioners alike.

This **CIRTL Resource Book** brings together a wide array of resources to help current and future faculty teach all students in their classrooms effectively, and develop Learning-through-Diversity skills. The user may also find it valuable to complement the information in the Resource Book with the other **CIRTL Diversity Resources** (http://www.cirtl.net/DiversityResources).

Diversity matters. Incorporating inclusive teaching principles into grant proposals, particularly in the area of "broader impacts," can open doors to new areas of expertise, increased funding, and improved career prospects. As faculty and future faculty develop and use inclusive teaching methods, they prepare the next generation of scientists to be successful in an increasingly diverse nation.

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Part One:
Preparing to Teach

Part One: Preparing to Teach

Before a course begins, consider:

- What, specifically, do you want your students to be able to accomplish?
- What concrete skills do you want them to develop by the end of the semester?
- What techniques will most effectively build these skills?
- How can you communicate these requirements through a thorough and well-written syllabus?

Teaching so that every student can be included begins long before the first day of class. For example, the simple act of including language such as “accessible” in course materials sends an important message to students. Throughout the course, varying teaching methods can allow more students to excel (Davis, 1993; McKeachie, 1994).

- What flexibility can you develop in your methods of instruction so that students with different learning styles can all benefit from the course?
- Are there adaptive technologies available that will allow students with disabilities to participate fully?
- And, since we live in a culture where stereotypes are common, are you aware of any preconceived ideas about your students that you may bring to the classroom?

In Part One of this resource book, we begin by giving you some simple and helpful tools to build student accomplishment, foster understanding, and facilitate participation and inclusion.

Planning a Course

Defining Instructional Objectives[1]

The first step in creating a high-quality course is to clearly define your educational goals and objectives. Educational goals are broad, overarching themes that will guide your course. Objectives are concise, explicit statements that describe what exactly you expect students to learn and the skills you hope they will acquire during your course. Establishing clear and detailed statements about your teaching goals and objectives can help you select appropriate teaching techniques, create learning activities, and choose evaluation and assessment methods. Even if you are not developing the course yourself or are a teaching assistant, it is still important for you to consider your goals in teaching your students and how you will reach those goals. Once you meet with students, it is important to take into consideration their personal goals for the course and their prior knowledge as well. (Information about getting feedback from students can be found later in Part One, under "Addressing Students' Needs").

> *Writing your educational goals first will guide you in creating learning objectives.*

Writing your educational goals first will guide you in creating learning objectives. The goals of your course are determined largely by your subject matter, the level of difficulty of your course, and your personal interests. Decide what your goals are for your students. At what level do you expect students to learn and perform? What skills do you want students to take away from your course?

Benjamin Bloom's taxonomy may be used to match course activities to desired learning outcomes. Bloom's taxonomy identifies three major categories of learning: cognitive, affective and psychomotor. Each category is listed on the following page, along with different levels of comprehension. Each level is increasingly more difficult and complex. Key terms that exemplify the level of understanding are also given.

Cognitive: development of intellectual skills, knowledge.	
1. Recall	define, describe, identify, know, label, list, match, name, outline, recognize, reproduce, select, state
2. Comprehension	convert, defend, distinguish, estimate, explain, extend, generalize, give examples, infer, interpret, paraphrase, predict, rewrite, summarize, translate
3. Application	apply, change, compute, construct, demonstrate, discover, manipulate, modify, predict, relate, show, solve, use
4. Analysis	break down, compare, contrast, diagram, deconstruct, differentiate, identify, illustrate, infer, relate
5. Synthesis	categorize, combine, compose, create, devise, design, explain, generate, organize, rearrange, revise, summarize, write
6. Evaluation	appraise, compare, conclude, criticize, critique, defend, describe, discriminate, evaluate, explain, interpret, justify, relate, support

Affective: feelings, emotions, values or attitude.	
1. Receiving or attention	asks, chooses, describes, selects, replies
2. Responding	answers, assists, discusses, performs, practices, presents, reads, tells
3. Valuing	demonstrates, explains, follows, initiates, invites, justifies, proposes, reports, shares
4. Organization	break down, compare, contrast, diagram, deconstruct, differentiate, identify, illustrate, infer, relate
5. Internalizing values	acts, discriminates, influences, listens, modifies, performs, qualifies, questions, revises, serves, solves, verifies

Psychomotor: manual or physical skills.	
1. Perception	choose, describe, detect, differentiate, distinguish, identify, isolate, select
2. Readiness to act	begins, explains, moves, proceeds, reacts, shows, volunteer
3. Guided response	copy, trace, follow, react, reproduce
4. Mechanism	assemble, construct, dismantle, fix, manipulate, measure, mix, organize, sketch
5. Adaptation	alter, change, rearrange, reorganize, revises, vary
6. Origination	arrange, build, combine, compose, construct, create, initiate, make

(Bloom, 1956)

Use these levels of comprehension and descriptive verbs to help guide you in writing course objectives. For example, if you are teaching an entry-level course, you may not emphasize more advanced cognitive skills such as synthesis or evaluation. If one of your goals is to teach students how to perform chemistry experiments, break this general aim down into its component parts for your objectives:

- ☑ to formulate a hypothesis,
- ☑ to design an experiment,
- ☑ to collect data,
- ☑ to analyze it,
- ☑ to draw conclusions, etc.

Then, break each of these into its component skills. The following is an example of course objectives and goals from an Inorganic Chemistry course:

Course Objectives: Inorganic Chemistry

This course will provide an audience of junior and senior students majoring in chemistry or the allied chemical sciences with a foundation in the theoretical principles and descriptive chemistry of the elements. The objective is to introduce the concepts of symmetry and their application to molecular orbital theory, and to use this theoretical framework to understand the chemistry of the elements, with a focus on the transition elements.

By the end of the course it is expected that every student will:

1. Be able to determine the point-group symmetry of a molecule and use the point-group symmetry to deduce select spectroscopic properties.
2. Be able to derive a molecular orbital diagram for a molecule in an ideal geometry and use the diagram to aid in prediction of chemical behavior.
3. Have a basic knowledge of the descriptive chemistry of the element families and be familiar with literature sources that can provide further information.
4. Be able to predict the chemical behavior of significant classes of inorganic molecules, including transition metal coordination compounds and organometallic compounds.
5. Be able to propose several plausible reaction mechanisms for a given chemical transformation, derive rate laws for these mechanisms, and interpret experimental kinetic data to provide support for or evidence against a given mechanism.
6. Be able to access the chemical literature to find specific chemical information.

Teaching and Learning Styles: the Academic Culture[2]

List of Learning Styles[3]	
Physical Modality	Visual Verbal Sensing/Kinesthetic, Tactile
Analytical Progression	Global Sequential
Learning Process	Active Reflective
Level of Abstraction	Sensing, Concrete, Applied Intuitive, Abstract, Theoretical

Learning Styles

In recent decades, studies have shown that students have varying learning styles, and that no single teaching style fulfills all students' needs. Learning styles have very little to do with the students' motivation or attitude toward the class or the material. Often, professors and TAs complain that some students do not apply themselves to their studies, and therefore do not learn well. However, it may be that the teacher simply has not yet addressed these students' particular needs in class, and that new approaches will reach the students more effectively. A student's learning style has to do with the way he or she processes information in order to learn it and then apply it.

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Professor Richard Felder of North Carolina State University (Felder and Porter, 1994) has described some of these varied learning preferences:

Some students may be **visual learners**, and prefer to study graphs, look at models and pictures, and take notes to review later. Such students react well to extensive blackboard use, (especially drawings, models, etc.) and handouts with illustrations.

Verbal learners are likely to absorb reading materials and lectures more easily than other students are. They seem to learn best from written materials, rather than from visual materials such as graphs and illustrations. Most university teachers are verbal learners, and thus find it easiest to relate to and teach such students.

Both **tactile** and **kinesthetic learners** prefer "real-life" connections to the topic, rather than theoretical approaches. They are "active learners" who learn best by physically doing things, rather than reflecting about them by themselves, and thus they react well to group work. They may also often learn by induction rather than deduction.

Sensing learners are tactile learners who favor subjects that allow them to work with their hands. These students learn best by handling objects as they apply their knowledge: they enjoy using objects of interest to the topic, such as original documents, photos, magazines or natural objects. Sensing learners may be kinesthetic learners who learn and remember by moving around physically. Moving students into small groups or pairs for discussion, having them participate actively in an experiment, or getting them to "act out" a debate by placing them on opposite sides of the room will help this type of student to remember the content of the discussion.

Most instructors and students find deductive methods – starting with abstractions or principles, rather than beginning with experience or hard data – to be easier to use in a course setting; however, they are not as effective in teaching as inductive methods are.[4]

These different learning styles explain why, in most classes, the student evaluations show that some students see group work as the most important part of their learning experience, while others from the same class complain that they dislike group work and find it unhelpful. Providing a variety of approaches to the material can keep most of the students engaged in the class throughout the semester.

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Global learners seem more likely than others to see a project as a whole and have trouble breaking it down into its component parts. Teachers who expect them to start analysis from abstract concepts in order to reach a conclusion may find themselves as frustrated with the result as the students are. Abstractions may be difficult for this kind of learner, because they grasp information in large chunks and have a hard time analyzing a topic from incomplete information. This type of student is excellent at synthesis, and by the end of a class may even outpace his or her peers in coming to appropriate conclusions quickly; however, he or she often has trouble understanding material when first faced with a variety of pieces of information that make an incomplete picture.

Sequential learners, on the other hand, are good at analysis of concepts because they learn linearly. When doing a project, they can take partial information and organize it into a logical order, and they can see what must be done first, next and last. They are patient with the fact that a typical class gives them information in a certain order, and that they must wait until the end of the semester to get the full picture the teacher is trying to present. Since most classes are organized sequentially, this kind of learner excels in the typical college class.

No teacher can make all students happy all the time; partly because of the diversity of learning styles in any class, and partly because each person uses a particular mix of the learning styles discussed above. No student is 100 percent a global learner or 100 percent a tactile learner. Preference for one style over another may be strong, moderate, or balanced. However, it is important to recognize that learning styles differ, and that your students may not learn well if you use only your style.

In order to teach everyone most effectively, a teacher cannot consistently ignore a whole sector of the class simply because their learning styles do not correspond to the teacher's preferred teaching habits. To reach as many students as possible, the teacher must incorporate varying teaching techniques and strategies into the classroom. Lectures may be appropriate for verbal learners, and group work may be appropriate for kinesthetic learners, but using any teaching style to the exclusion of the others will also exclude those students who do not learn best by that style.

Felder (1993) has devised a useful list of five questions teachers can ask themselves as they get to know their students:

Dimensions of Learning Style[5]

A student's learning style may be defined in part by the answers to five questions:

1. What type of information does the student preferentially perceive: sensory sights, sounds, and physical sensations, or intuitive memories, ideas, and insights?
2. Through which modality is sensory information most effectively perceived: visual pictures, diagrams, graphs, and demonstrations, or verbal sounds, written and spoken words, and formulas?
3. How does the student prefer to process information: actively, through engagement in physical activity or discussion, or reflectively, through introspection?
4. How does the student progress toward understanding: sequentially, in a logical progression of small incremental steps, or globally, in large jumps, and holistically?

Such questions will provide the basis for choosing a balance of teaching methods and techniques that are the most effective. Any teacher must eventually decide which mix works best for the subject matter and for the kinds of students in a class. The questions themselves suggest that a teacher should begin with a variety of approaches, and, after deciding which are the most effective for the students, select techniques to add to his or her repertoire.

Teaching Techniques to Address All Learning Styles[6]

- Motivate learning. As much as possible, relate the material being presented to what has come before and what is still to come in the same course; relate it to material in other courses, and connect it to the student's personal experience (global).

- Provide a balance of concrete, sensing information (such as facts, data, real or hypothetical experiments and their results) and abstract, intuitive concepts (such as principles, theories and models).
- Balance material that emphasizes practical problem-solving methods (sensing/active) with material that emphasizes fundamental understanding (intuitive/reflective).
- Provide explicit illustrations of intuitive patterns (such as logical inference, pattern recognition and generalization) and sensing patterns (such as observation of surroundings, empirical experimentation, and attention to detail). Encourage students to exercise both patterns (sensing and intuitive). Do not expect either group to be able to exercise the other group's processes immediately.
- Follow the scientific method in presenting theoretical material: provide concrete examples of the phenomena the theory describes or predicts (sensing), then develop the theory or formulate the model (intuitive/sequential).
- Use pictures, schematics, graphs and simple sketches liberally before, during and after the presentation of verbal material (sensing/visual). Show films (sensing/visual), and provide demonstrations (sensing/visual), hands-on if possible (active).
- Use computer-assisted instruction when possible; sensors respond very well to it (sensing/active).
- Do not fill every minute of class time with lecturing and writing on the board. Provide intervals, however brief, for students to think about what they have been told (reflective).
- Provide opportunities for students to do something active besides transcribing notes. Small-group brainstorming activities that take no more than five minutes are extremely effective for this purpose (active).
- Assign some drill exercises to provide practice in the basic methods being taught (sensing/active/sequential), but do not overdo them. Also, provide some open-ended problems and exercises that call for analysis and synthesis (intuitive/reflective/global).
- Give students the option of cooperating on homework and class assignments to the greatest possible extent (active). Active learners generally learn best when they interact with others; if they are denied the opportunity to do so, they are deprived of their most effective learning tool.

- Applaud creative solutions, even incorrect ones (intuitive/global).
- Talk to students about learning styles, both in advising and in classes. Students are reassured to find their academic difficulties may not all be due to personal inadequacies. Explaining to struggling sensors or active or global learners how they learn most effectively may be an important step in helping them reshape their learning experiences so that they can be successful (all types).

The Academic Culture and Teaching Styles[7]

As you saw in the previous section, students' learning styles vary, and a teacher might have a complex mixture of students in a single class. However, the average college teacher is much more likely to be sequential, verbal and reflective than his or her students are.

Traditionally, college teachers prefer to organize their class in a "logical" order during the semester, starting with simple premises and working up to a more complex view of the field in question. They use lectures and discussions as the primary means of transmitting information to the students, and classes are usually conducted in a deductive manner, with principles clearly laid out, and with the expectation that the students can draw consequences and come up with applications.

> *A dominant "academic culture" exists in college classrooms which encourages sequential, verbal and reflective learners to progress quickly to advanced positions in a field.*

Students are encouraged to work individually, and achievement is measured by their ability to produce "original" materials or answers. Instructors generally emphasize individual accomplishment, verbal assertiveness in class discussion, and competition for grades instead of collaboration. As a matter of fact, the academic community often discourages or even punishes collaboration, because it fears the heightened potential for plagiarism in a collaborative effort. Such a teaching method encourages learners who already share the teacher's learning style, but it slows down learners who must adapt to conditions of learning that do not come naturally to them.

Thus, a dominant "academic culture" exists in college classrooms, which enables sequential, verbal, and reflective learners to progress quickly to advanced positions in a field. This leaves behind equally intelligent and resourceful students who must wonder if there is a place for them to excel in the academic world.

Learning Styles[8]

Whatever the similarities and differences in learning styles and intelligence among our students, we can help all of them by employing a range of active learning approaches (talking and listening, writing, reading, reflecting) and varying teaching techniques and strategies (lectures, videos, demonstrations, discovery labs, collaborative groups, independent projects). Moreover, by using a variety of teaching techniques, we can help students make sense of the world in different ways, increasing the likelihood that they will develop conceptual understanding.

Active Learning

Those who have studied the learning of science, technology, engineering and mathematics (STEM) have concluded that students learn best if they are engaged in active learning, if they are forced to deal with observations and concepts before terms and facts, and if they have the sense that they are part of a community of learners in a classroom environment that is very supportive of their learning.

It is important to "fit" your teaching techniques to both your course objectives and to your students' varied learning styles.

When the focus is on meaning, rather than solely on facts, students develop their conceptual abilities. They assimilate information by incorporating new concepts or by using information to differentiate among already existing concepts. This is not necessarily at the expense of their development of algorithmic abilities, because conceptual understanding gives a context for the application of problem-solving methods.

The ways in which your objectives are carried out will either facilitate or hinder what you are trying to accomplish with students. This is why it is important to "fit" your teaching techniques to both your course objectives and to your students' varied learning styles.

Interactive Teaching Techniques[9]

The following are some interactive teaching techniques you might try in your class:

- ☑ Have students write a question on a piece of paper before or during class and turn it in for you to answer in a "press conference" format.
- ☑ Put students into pairs or "learning cells" to quiz each other about the subject matter.
- ☑ Have students apply the subject matter by solving real-life problems.
- ☑ Give students red, yellow, and green paper cards representing different answers, and periodically call for a vote on a question by asking for a simultaneous showing of the cards.
- ☑ Roam the aisles of large classrooms and carry on running conversations with students as they work on problems (a portable microphone helps in a large hall).
- ☑ Ask a question directed to one student and wait for an answer.

- ☑ Place a suggestion box in the rear of the room, and encourage students to make written comments every time the class meets.
- ☑ Do oral, show-of-hands, or multiple-choice tests for summary, review, and instant feedback.
- ☑ Grade quizzes and exercises in class as a learning tool.
- ☑ Have students keep three-week, three-times-a-week journals in which they comment, ask questions, or respond to course topics.
- ☑ Make collaborative assignments for several students to work on together.
- ☑ Assign written paraphrases and summaries of difficult reading.
- ☑ Give students a take-home problem relating to the day's lecture.

Asking Questions [10]

Instructors can help students become active learners by motivating them with open-ended questions, puzzles, and paradoxes. What happens when. . . ? Why does that happen? But how can that be, when we know that. . . ?

Full integration of new knowledge is enhanced by time to reflect. Reflection is especially beneficial immediately following the presentation of new, challenging material. One effective method (Rowe, 1974) is to provide, after ten minutes of lecturing, short periods (a minute or two) for students to think. The necessary structure can be provided by a pertinent question.

An alternative to asking questions is to ask students to summarize some important ideas from a previous discussion or the reading assignment. This focuses their attention and gives the teacher an opportunity to assess their level of understanding. Because students' disposition to learn can be influenced by the knowledge or mental frameworks they bring to class, assessing for prior knowledge is an essential component of teaching for active learning. Students often approach learning situations with misconceptions or with prior knowledge that actually impedes learning. Students are most likely to change their beliefs if they first develop dissatisfaction with those beliefs and recognize possible alternatives as they prepare themselves to adopt a new, more acceptable view.

The following is an example of how a Harvard physics professor used active learning in his large lecture.

Introduction to Physics at Harvard University

Professor: Eric Mazur

Enrollment: Approximately 250 students

In 1989, I read an article in the American Journal of Physics that contained a test to assess understanding of Newtonian mechanics. I gave the test to my students at Harvard and was shocked by the results — the students had merely memorized equations and problem-solving procedures, and were unable to answer basic questions, indicating a substantial lack of understanding of the material. I began to rethink how I was teaching, and realized that students were deriving little benefit from my lectures, even though they generally gave me high marks as a lecturer. So I decided to stop preaching and instead of teaching by telling, I switched to teaching by questioning using a teaching technique I have named "peer instruction."

My students now read the material before class. To get them to do the reading, I begin each class with a short reading quiz. The lecture periods are then broken down into a series of digestible snippets of 10 to 15 minutes. Rather than regurgitating the text, I concentrate on the basic concepts, and every 10 or 15 minutes I project a "Concept Test" on the screen. These short conceptual questions generally require qualitative rather than quantitative answers. The students get one minute to think and choose an answer. They are also expected to record their confidence in their answer. After they record their answers, I ask the students to turn to their neighbors and to convince them of their logic. Chaos erupts as students engage in lively and usually uninhibited discussions of the question. I run up and down the aisles to participate in some of the discussions — to find out how students explain the correct answer in their own words and to find out what mistakes they make.

After one or two minutes, I call time and ask students to record a revised answer and a revised confidence level. A show of hands then quickly reveals the percentage of correct answers. After the discussion, the number of correct answers and the confidence level typically rise dramatically. If I am not satisfied, I repeat the cycle with another question on the same subject.

I have been lecturing like this now for more than four years. During this time the students have taught me how best to teach them. As for the students, nothing clarifies their ideas as much as explaining them to others. As one student said in a recent interview: "There is this 'Ah-hah!' kind of feeling. It's not that someone just told me; I actually figured it out. And because I can figure it out now, that means I can figure it out on the exam. And I can figure it out for the rest of my life."

Choosing and Using Instructional Materials[11]

Advantages and Disadvantages of Using Textbooks

Books are a highly portable form of information and can be accessed when, where, and at whatever rate and level of detail the reader desires. Research indicates that, for many people, visual processing (e.g., reading) is faster than auditory processing (e.g., listening to lectures), making textbooks a very effective resource (McKeachie, 1994). Reading can be done slowly, accompanied by extensive note taking, or it can be done rapidly, by skimming and skipping. There are advantages to both styles, and you may find it useful to discuss their merits with your students.

Although a well-written book can engage and hold student interest, textbooks have several major limitations. Books are not inherently interactive. However, if students are encouraged to ask questions while they read, seek answers within the text, and identify other sources to explore ideas not contained in the text, they will become active readers and gain the maximum benefit from their textbooks. To meet the needs of a broad audience, texts are often thick, which can overwhelm students seeking key information. Texts are often forced to rely on historical or dated examples, and they rarely give a sense of the discovery aspects of research and the disorganization of information facing modern researchers.

> *Texts… rarely give a sense of the discovery aspects and disorganization of information facing modern researchers.*

How to Choose and Use an Appropriate Textbook

Before selecting a text, it is important to know what books are currently on the market. Colleagues who teach the same or a similar course (in your department or at other institutions) are good sources for ideas and information. For example, they may know whether a textbook contains errors. Your campus bookstore's manager can provide the name and phone number for textbook sales representatives from many different companies. Science education publications carry advertisements from major publishers, and some feature a book review section or annual book buyer's guide. Professional society meetings serving faculty in your academic discipline also provide a chance to talk to publishers and see their new textbooks. Many companies will supply review copies to potential textbook adopters, in return for information about the course in which it might be used.

> *…The objectives of a textbook must be consistent with the objectives and goals you set for the course.*

There are a number of factors to consider when selecting a textbook. To be of greatest value to students, the objectives of a textbook must be consistent with the objectives and goals you set for the course. Authors often try to meet particular objectives in their books, and a given book may or may not meet your goals. Skim the preface to see whether you share the author's approach to the subject. Consider how the table of contents aligns with your course syllabus and teaching philosophy:

In addition to content, evaluate the text structure and layout. Studies indicate that the "principle-first" structure, in which a concept or principle is stated explicitly and then supporting evidence is presented, is most effective for long-term retention and understanding by novice readers.

Using the Textbook Effectively

Once you have chosen a textbook, help your students use it effectively. Allow time during the first week of class to introduce the text and outline your strategy for its use. Encourage your students to use the text by asking them questions that require higher-order critical thinking skills drawing on and extending its material, methods, or examples. Simple factual questions are of little value to long-term retention or true understanding. Higher-order questions help students to think about readings, ask questions, integrate material, and develop answers in their own words.

Encourage your students to use the text by asking them questions that require higher-order critical thinking skills.

When appropriate, help students to understand that a textbook is not always the final authority on a topic, particularly in fields where new information is discovered at a very fast rate. Students may learn that it is O.K. to question the text if the instructor also openly disagrees with some interpretations or approaches in the book. The instructor can use different interpretations as examples of unresolved problems and illustrate critical thinking by presenting reasons and evidence for differing opinions. However, be careful not to develop such a negative attitude toward the text that students stop using it, or question the teacher's judgment for choosing it.

What If I Can't Find the "Perfect" Textbook?

After a thorough search, you may find that the book you want simply does not exist. Publishers have realized this and have taken steps to customize their products to meet faculty needs. It is possible to select certain chapters of a given book to be bound as a volume. It is also possible to combine chapters of different books from the same publisher. This approach offers considerable flexibility, given that many smaller textbook publishers are now subsidiaries of larger corporations. Another option is to combine resources from several different publishers and to offer students a "course packet" instead of a textbook. Many college bookstores and copy centers will work with faculty members to collect chapters, readings, and supplements. They obtain the required copyrights, and bind and sell custom-designed materials tailored for a particular course.

Considerations in Choosing Instructional Material

- Does the material match your educational goals? What additional materials will you need to give to students?
- Does the material present information in a variety of ways, using text, pictures, graphs, and real-world examples?
- How will students use the materials to reach your course objectives? You should suggest to students how to get the most out of the materials.
- Is the material accessible and clear to your students' level of understanding? Make sure that students will have sufficient background to comprehend the material. After a few weeks in class, ask students how they feel about the materials, and evaluate the materials' effectiveness at the end of the course.
- Consider building an online component of the course that offers lecture notes, supplemental learning materials, and sample tests.
- Select textbooks with an accompanying study guide or interactive CD-ROM for additional learning opportunities.
- Supplement the main textbook with additional readings. This alerts students to the existence of other resources and new research.
- Select material with gender-neutral language and no stereotypes. If this is not possible, point out these problems in class, and give your students an opportunity to discuss them.

Do not assume that all students will recognize cultural or historical references familiar to you. Consider administrating a diagnostic pretest to determine what your students know before referring to a specific cultural reference.

Include multiple perspectives on each topic of the course rather than focusing solely on a single perspective. For example, if discussing global climate change, try to bring up the documents submitted to the U.N. by Indigenous Nations concerning climate change and related policy. Also, it would be important to include a discussion of climate change impacts on Native lands and homelands when addressing the U.S. Global Change Research Program's National Assessment Synthesis Report on Climate Change.

Include materials written or created by people of different backgrounds and/or perspectives. If all materials have only male European or American scientists, the message sent to students may be that you devalue the contributions of and scholarship produced by people of color and women. Even if you teach only majority students, you can set a good example by including diverse perspectives and opinions.

Use a text that reflects new scholarship and research about previously underrepresented groups, discussing the contributions made to the field by women or various ethnic groups.

Use a text that reflects new scholarship and research about previously underrepresented groups, discussing the contributions made to the field by women or various ethnic groups, examining the obstacles these pioneering contributors had to overcome. However, do not make such issues seem like "special topics"— make sure that no single group is held up as the norm.

Examine course content for inaccurate information and the absence of relevant perspectives. Prepare for each class session by reading upcoming assignments in order to identify omissions, misleading interpretations, and intentional or inadvertent expressions of personal opinion by the author. You may then alert students to problems with the text and encourage students to read critically themselves. For example, an engineering course might use a book that focuses on the advantages of nuclear power. Since this is something there is current disagreement about, if the book does not acknowledge health risks to those living near nuclear waste disposal sites, students might be prompted to consider and discuss their degree of agreement with the text.

Create a classroom climate that encourages and expects questions about and critiques of course content. Such a climate will help to create a norm of critical thinking that will facilitate the learning process for all students. As students share their critiques with the class, other students will benefit by being exposed to different interpretations, perspectives, and concerns regarding course material.

Writing a Syllabus

The syllabus is a document you give to your students that provides relevant course information, and provides a great way for you to clearly communicate your course objectives and goals to your students. It is important to take students' personal goals and past educational experience into consideration as well. Consider putting the syllabus and other relevant materials online, such as readings and sample tests.

Syllabus Checklist[12]

The more information that you can give the student, the better. Do not be afraid of generating a long syllabus. However, if it does become more than a few pages, consider attaching a table of contents.

Below is a list of information which students need to see on their first day of class:

☑ *Basic Information:*
Course title, course number, number of credits, current year and term, meeting time and location, your name, location of your office, office phone number, e-

mail address, and names, offices and phone numbers of other instructors. Identify your preferred method of communication.

☑ *Office Hours:*
The times you will be available to meet with students. Try to be available at a variety of times in order to accommodate many schedules. Invite students to meet with you during your office hours to discuss their accommodation and/or learning needs.

☑ *Prerequisites:*
Required classes, knowledge, skills or experience for the course.

☑ *Course's Purpose:*
What the course is about and why it is interesting to you.

☑ *Learning Goals:*
Competencies/skills/knowledge that students are expected to demonstrate at the end of the course. (Ideas on how to generate these goals can be found under "Defining Instructional Objectives.")

☑ *Course Structure:*
The conceptual design behind the course. Sequence topics so that major concepts are introduced early and can be reinforced through application to new situations.

☑ *Textbooks & Readings:*
Titles, authors, editions and local booksellers who carry the titles. Select textbooks with an accompanying study guide or interactive CD-ROM for additional learning opportunities, if possible.

☑ *Additional Required Materials and Equipment:*
Do the students need to buy calculators, computers, computer software, art supplies, drafting materials, etc.? If they do, be specific about what brands or models you recommend.

☑ *Assignments, Term Papers and Exams:*
Be specific. Describe the nature and format of assignments. What format are the tests: short answer, essay, or multiple choice? What are the topics, expected lengths, and due dates of the term papers? Try to anticipate questions, as well as confusions that may arise later.

☑ *Grades:*
Describe how you will calculate grades (e.g., whether or not you will use a curve). Provide specific criteria that you will use when evaluating assignments, if relevant. (For more information, see "Assessing Student Performance" in Part Three.)

☑ *Course polices:*
How do you deal with lateness, absences, late homework, requests for

extensions, make-up tests or assignments, cheating and plagiarism? Be very explicit and firm. Is the date for the final exam set in stone?

☑ *Ground rules:*
Explain what type of behavior and attitude is expected from students. Create a climate of mutual respect, openness and inquiry.

☑ *Course schedule:*
Provide a schedule of events which gives a topic of discussion or lecture for each day and what assignments or readings should be completed for that day. Topics and activities may be tentative, but exam dates and required reading should be reasonably fixed. Students are attempting to manage their workloads for the term at the beginning, and major last-minute changes in the syllabus can be very upsetting.

☑ *Other things you might consider:*
Give your students tips/advice on how to approach studying for this course. Recommend that they take a look at old exams if these accurately reflect your testing style for this course. Talk about how you feel about extra credit. Make suggestions on how students can make the most of an office visit, or provide evaluation and feedback to you.

If you wish, make your syllabus informal and friendly. Be encouraging and enthusiastic about the coming experience. Encourage students to visit you in your office and say hello. Assure them that you want to help them all succeed in mastering the content of the course.

Using the Syllabus in Class[13]

First, check over the final typed copy for mistakes and typos. If you do not spot them, students will. Hand out the syllabus on the first day of class. This lets the students know that you are well prepared. It provides an easy way to begin the interaction with students, and to reduce some of the uncertainty and anxiety of the first class meeting.

You will need to review and discuss the syllabus with the students, to answer any questions that they may have and to provide appropriate amplification where necessary. You will probably find that most student feedback will be generated by the section on grading. It is vital to have enough copies of the syllabus; one should allow for the need to replace lost copies and to accommodate students who have registered for the class but do not appear on the initial roster. If changes are made in the syllabus later on, it is a good idea to give them to students in writing. Much ambiguity and confusion can result from half-remembered, spoken promises.

Summary of Course Planning

- ☑ Write clear, explicit objectives and goals for your students that use cognitive, affective, and psychomotor comprehension, such as written, oral, and presentation assignments.
- ☑ Choose visual, auditory and kinesthetic teaching techniques that match your objectives, such as watching videos, holding discussions, using groups, and inviting guest speakers.
- ☑ Choose teaching materials (e.g., texts, readings) that present research and innovations in the field by people of a variety of demographic backgrounds.
- ☑ Write a syllabus that encourages students to get help from you and to seek additional campus resources if they have questions on course work. The syllabus should also set an open and respectful climate for the classroom.

Addressing Students' Needs

Importance of Knowing Your Students[14]

To effectively choose teaching methods and help students learn, you must first know something about whom you are teaching. Your students will come from very different backgrounds and have various learning needs. You may have students that graduated from high school when they were 16 and are still minors. Or you may have students that have been out of school for 20 or 30 years. Some students may have grown up in the college town, while others may be from across the globe and speak a completely different native language. Some students may have gone to schools without honors or advanced placement science and math courses, while others may have never been encouraged to pursue science or math at all.

Your students will come from very different backgrounds and have various learning needs.

Considerate Communication

Many students, regardless of their gender or cultural background, feel discouraged when they see inconsiderate behavior on the part of professors, TAs, or other students. Witnessing repeated problems may cause these students to question their major, or even their aspirations for a college degree. To foster class participation and student success, it is essential to provide a friendly and respectful classroom.

Each of us sees through the lens of our own experience. Being aware of stereotypes and inappropriate language is the first step to developing a genuine awareness of the other person's point of view.

Being aware of stereotypes and inappropriate language is the first step to developing a genuine awareness of the other person's point of view.

Providing a welcoming environment is not as challenging as it may sound. It is about realizing the ways that some students may be misjudged by peers and instructors, and how this affects them. Treating students with consideration and interest, and encouraging them to treat each other likewise, will improve the quality of life at your university. Education is the beginning of your students' professional lives. Now is the time to make your words and example count.

Knowing Your Students' Backgrounds

> *By customizing your course to students' needs, you can teach more efficiently and effectively.*

Knowledge about students will enable you to refine lectures, class discussions, comments, illustrations, and activities so that they are more effective learning experiences. References to student interests, backgrounds, knowledge, and even anxieties can make the class seem more personal and the material more accessible.

Not all students will have the same background in your field. By assessing students' comprehension levels of the subject, you can modify your own teaching to fit their needs. By customizing your course to students' needs, you can teach more efficiently and effectively.

Your first step will be to find out more about your students. On the first day of class, hand out a questionnaire. You should find out what previous classes students have had in your field and related subjects. You can list basic terminology you expect students to understand, and ask students to mark the words they do not understand or feel uncomfortable with. Ask your students if their attendance or participation in class and on assignments will be affected by their religion, disability, or any other unique situation. Leave an area for students to write down any special accommodations they may need for learning disabilities, work or family obligations, etc.

Planning Considerations[15]

There are a number of issues that should be taken into account during the planning process for any class. You need to become comfortable with your level of knowledge about certain groups and seek ways to inform yourself (e.g., through experiences, readings, and/or conversations with faculty, peers, and students who are knowledgeable about the particular groups). Below you will find examples of issues to consider during the planning process.

Accommodations

Students may have religious holidays and practices that require accommodations at certain times during the academic calendar year. Students with disabilities may also require special accommodations. Consider students' needs when assigning evening or weekend work. Be prepared to make accommodations for students who feel uncomfortable working in labs or at computer stations during the evening because of safety concerns. Students who are parents, particularly those who are single parents, may also appreciate alternatives to evening lab work or weekend field trips, as will students who work part-time.

Attendance

If you grade on the basis of attendance, it is important that you record all students' attendance at every class session (whether or not you use the information) rather than collecting a mental record of absences. Students who are different in a highly visible way (women who wear Islamic clothing, African Americans or Asian Americans in a predominantly Caucasian class, students who use wheelchairs, etc.) can be penalized because of their visibility. In particular, absences of such students may be noticed more easily and this may inadvertently and unfairly affect how you assess their performance.

Cultural Reference Points

Instructors who use examples drawn only from their own experiences may fail to reach all students in the class. Given that examples are designed to clarify key points, you should collect examples from a variety of cultural reference points. For example, in 1995/1996, "Friends" was a sitcom that received high ratings. However, this show was less popular among many African American people than shows like "Living Single" and "Martin." Similarly, when using sports examples it is important for instructors to include sports in which women predominate (e.g., track & field, figure skating, gymnastics, tennis, softball) as well as those in which male participants predominate (e.g., hockey, football, baseball).

These concerns can also be offset by asking about students' familiarity with an example before discussing it or asking students to produce examples of their own. You can also explain examples fully in order to reach a diverse classroom. Bring in guest lecturers. As appropriate, you can broaden and enrich your course by asking faculty or off-campus professionals of different ethnic groups or cultures to make presentations to your class.

Safe Discussion of Controversial Topics

Class sessions that address controversial topics may result in any of the following unintended outcomes:

1. altercations between individual students or groups of students
2. silence from students who feel intimidated or fear conflict
3. the assertion and perpetuation of false stereotypes or problematic assumptions
4. the expression of offensive speech

When working with a particular controversial topic, anticipate possible responses and how you might deal with differing yet passionate views on that topic.

There are no easy answers for dealing with these situations when they occur. It is best to work toward the prevention of these occurrences by investing time in the planning process.

When working with a particular controversial topic, anticipate possible responses and how you might deal with differing yet passionate views on that topic.

You should plan strategies that provide structure for these discussions and that foster students' ability to express their own ideas well, while also increasing their ability to listen to and learn from others. In the interest of free speech, students should be encouraged to honestly share their views during discussions. Be prepared, however, to correct stereotypes and challenge students' assumptions when comments are shared. It can be a difficult task to reconcile the tension between challenging offensive speech and not suppressing free speech. You should also consider your own response to emotion in the classroom and use this awareness to inform the planning process.

Establishing agreed-upon ground rules early in the class can be an important aspect of productive class discussions. If ground rules are established early, students will need to be reminded periodically of the rules throughout the semester, especially if their behavior suggests that they are ignoring them. If such rules are not established at the beginning of the semester, it is necessary to establish them when a problem becomes apparent. (For a list of important ground rules for discussion, go to the section on Discussion).

It is also helpful to focus on group processes. Activities and assignments during the first weeks of the course should include opportunities for instructors to get to know each student and for students to get to know one another. Establishing rules for classroom dialogues, building a trusting and open environment, modeling appropriate behavior during dialogues, and giving students the opportunity to practice these behaviors are important for positive dialogue. If you and your students engage in these behaviors early on, when problems arise, you will be able to address the problem by discussing the rules and appropriate behaviors.

Getting to Know Your Students[16]

Responding to Student Identities

☑ *Invite all students to contribute to class discussion, even if you assume that the discussion is more relevant to some students than others.*
Students (regardless of background) do not like being forced to serve as the spokespeople for their groups. Students also do not appreciate being expected to know everything about issues relating to their groups or dealing with the assumption that all students from their group feel the same way about an issue.

> *Students from underrepresented groups may also feel a self-imposed pressure to portray themselves in a good light so they do not reinforce stereotypes about their group.*

☑ *Be sensitive to the experiences of visibly underrepresented students in your class.*
Students with identities that are underrepresented may face certain challenges that unfairly compromise their learning environment. For example, students of color may be penalized because of the stereotypes associated with the way they look and dress. In a biological science course, after 9/11, an American Sikh student did not feel safe attending class due to the backlash against people who appeared to be of Arab or Middle Eastern descent. He had even received death threats. The professor did not allow him to retake a test, and this unfairly affected his motivation and grades.

Students from underrepresented groups may also feel pressure to portray themselves in a good light so they do not reinforce stereotypes about their groups. Whereas "majority students" can slack off from time to time when working within groups, occasionally show up late to class, or be absent without peers attributing their behavior to membership in particular groups, students from underrepresented groups often sense that their behavior is interpreted as a reflection on their groups. Although there may be little you can do to relieve this self-imposed pressure, you can be thoughtful about your interactions with these students and make an effort not to publicly discuss students' performance or behavior.

Inequities in the Classroom

☑ *Be aware of gender dynamics in classroom discussions.*
Even when women are in the majority, men may sometimes consciously or unconsciously dominate class discussions or interrupt women. Monitor the occurrence of this behavior and encourage women to speak up, at the same time as discouraging men from dominating the discussion.

☑ *Be careful not to respond to comments in ways that students might interpret as dismissals.*
You should give sufficient attention to (a) students' comments that differ from the majority of students' views or your own views, (b) students' views that are based on experiential knowledge, and (c) women's views in predominately male classes or traditionally male fields. Be aware of differential feedback given to students who differ on some aspect of their social identity (gender, ethnicity, disability, sexual orientation, etc.). For example, you should notice whether you speak down to women or "brush off" their questions, yet give men responses that are informative and detailed.

Conflict in the Classroom

- ☑ *Respond to classroom conflict in a manner that helps students become aware of the "learning moment" this conflict provides.*
  Heated discussions need to be facilitated in a manner that does not result in hostility among class members and a sustained bad feeling in the room. You can avoid these outcomes by encouraging students to tie their feelings and conflicts to the course material and by looking for underlying meanings and principles that might get buried in the process of class conflict. Students appreciate tensions between groups in the class being recognized and effectively addressed.
- ☑ *Recognize student fears and concerns about conflict.*
  Students enter a class with different levels of experience and comfort with conflict. It is important to normalize the experience of conflict in the classroom, particularly in classes that focus on controversial topics. This can be accomplished through explicit discussion of student experiences with conflict, and through the use of structured discussion exercises.
- ☑ *Maintain the role of facilitator.*
  One of the challenges of teaching is maintaining the role of instructor under a variety of conditions. For example, you can get caught up in expressing your own perspective in heated discussions, or can become overly silent in discussions that go beyond your own knowledge base or experience. While these responses are understandable, such role abdication can create chaos in the classroom or force students to fill the abdicated facilitator role. In order to avoid this outcome, you should examine your typical responses to conflict. It can also be useful to find ways that you may admit your limits with respect to content areas while maintaining responsibility for the group process.

Even the most well-intentioned people make mistakes. As instructors, one of our jobs is to make the classroom a place where all learners feel confident enough to participate. This involves challenging our own assumptions as well as those of our students. One way to do this is to be aware of subtle behaviors that make some students feel unwelcome or excluded.

Students of Different Backgrounds[17]

It is vital that you view every student as a unique individual regardless of the student's cultural background, while at the same time respecting multiple cultural heritages and their impact on learning styles and classroom expectations. This is not a simple task, and there is no simple way to accomplish it. You cannot be prepared for every possible situation that might arise. Instead, focus on being open to different perspectives, being aware of stereotypes and prejudiced behavior in your class, and being ready to help every student in your class become engaged in the material and learn.

For instance, you would do well to try incorporating the achievements of Latino scientists into your curriculum to encourage and inspire Latino students. However, if the approach appears to be an act of tokenism, some of your students might feel as if they are being singled out or patronized. A better approach is to try and make the material relevant to students of many backgrounds whenever possible — even if your class does not contain every single demographic. Such an approach will benefit all of your students in expanding their knowledge and perspective.

You also should remember that the fact that a student is African American does not mean she or he will be able to or desire to speak about famous African Americans in science. Allowing students to express their views is beneficial whenever possible, but you should never expect someone to "speak for their people." Every student is a different person, and should only be asked to speak for himself or herself.

Adult Learners

The number of non-traditional students or "adult learners" in the classroom continues to increase. Adult learners are typically defined as students over the age of 25 who are returning to school after several years away from the classroom. For obvious reasons, the types of challenges facing a 45-year-old business woman or a 50-year-old father are going to be different than those of 18-23 year old students. Adult learners tend to expect practical and relevant application of materials, as well as meaningful assignments that do not feel like "busy work." In engineering or computer science, especially, some adult learners may have been working in related careers since before you were in high school. In some cases they may have a much better practical understanding of the course material than you do. Nevertheless, as a TA or instructor, you still have a great deal to offer them.

You should never expect someone to "speak for their people." Every student is a different person and should only be asked to speak for himself or herself.

You should be aware that adult learners, particularly those attending class part-time, can have much more intensive and unexpected non-academic demands on their time than other students. Care of sick children, work deadlines, work travel, and death of parents are just a few possibilities. Being flexible about such needs whenever possible is important. It can be a difficult task to balance the acceptance of late work and makeup exams while not appearing to favor one student over another.

Another difficulty which may affect adult learners more than younger students is the accessibility of campus social networks. Depending on the class and circumstance, many students could have access to previous exams and assignments from friends who have taken the course before. Students with limited campus social networks may not have access to these resources. If you know that many of your students are sharing old exams or have access to homework solutions, consider making these resources available to everyone.

When possible, it can help to talk to adult learners individually about their expectations of the class and any special circumstances that may affect their participation. It can seem intimidating to teach someone older than yourself. The most important thing to remember is that you have the same goals in mind — a valuable learning experience.

Educational Background

You can assist under-prepared students, especially those at the introductory level, by being sensitive to their needs. Students often lack numerical perspective, have an exaggerated appreciation for meaningless coincidence, or have a credulous acceptance of pseudoscience (Paulos, 1988). By better understanding the nature and extent of some of these problems in a class, you can tailor discussions, readings, and problem sets to address these difficulties directly rather than ignoring, overlooking, or avoiding them.

By showing an effort to speak in terms that students can understand, as well as teaching the students this new language and its vocabulary, teachers can help students to view themselves as partners in the learning process.

Language

Students who can converse in English and read the language reasonably well can still have difficulty learning the specialized vocabularies of the sciences and understanding classroom presentations, particularly in large lectures.

If you feel that it is important to know whether students speak or understand other languages, you should ask this question of all students, not just those to whom you think the question applies. If there are concerns about students' academic writing skills, it would be best to meet with the students during office hours to discuss their work. One of the questions you could ask as part of your data gathering protocol is, "What were the languages spoken in the environment in which you were raised?" Following this question with appropriate probing questions would give you an opportunity to find out whether students are native speakers of English and, if not, how recently they became fluent. It is important to identify the source of students' difficulties with writing (or speaking), because identification of the factors that contribute to these problems will influence the actions taken to address the problems.

You should find out if your students are unfamiliar with specialized language. Many words that scientists view as common are completely unknown to students. Several times during a term, ask students to jot down every unfamiliar word used in class that day. The words that appear most often on student responses should be defined and explained at the beginning of the next class. By showing an effort to speak in terms that students can understand, as well as teaching the students this new language and its vocabulary, teachers can help students to view themselves as partners in the learning process. If you make it a practice not only to define technical terms but to point out routinely how the different parts of the unfamiliar term contribute to its meaning, students will become familiar with prefixes, suffixes, and roots of technical terms, and they will be better able to discern the meanings of other words that contain these elements.

Discussing language, either a language from another country or a U.S. dialect, is often a sensitive issue with students from diverse cultural backgrounds. Students with language difficulties need to know, first of all, that their language of origin is respected. It is important to remember that all languages are culturally bound. Using visuals, synonyms, and examples when lecturing or in examination questions helps those with different language backgrounds to understand what is being communicated.

Students with language difficulties need to know, first of all, that their language of origin is respected.

Students with Disabilities[18]

The National Council on Disabilities (http://www.ncd.gov) reports that nearly 10 percent of college students have some kind of disability. Your department or university will have specific offices or individuals as well as guidelines for helping students who require additional services. For specific situations, making any necessary accommodations should be accomplished with the help of supporting university and departmental services, fellow teachers, and the student.

Make clear at the beginning of the course that you want to work with every student's strengths and weaknesses, and that you are happy to talk to any students about accommodations.

Every student in your class has a different set of strengths. Students with disabilities are there to learn. You should create a positive classroom environment that seeks to fully include all students. Make clear at the beginning of the course that you want to work with every student's strengths and weaknesses, and that you are happy to talk to any students about accommodations.

Some students in your class may have physical disabilities. These include but are not limited to visual or hearing impairments and issues with mobility. For students with visual or hearing impairments, you might need to make certain course material available in different mediums. Lab work can be more complicated. However in lab groups, students are usually given different tasks, some of which will be less dependent on physical constraints. It is important to allow students to experience the course work in similar ways to each other whenever possible.

Learning disabilities can take the form of developmental speech disorders, language disorders, or academic skills disorders such as dyslexia. Classroom assistants or special technology may be necessary in some cases. Since learning disabilities vary in kind and intensity, some students may not even be aware they have them. Most students develop coping methods which can often be effective. Some students may be reticent to talk to you about these issues. Creating an open classroom environment is key.

Teaching Strategies: Non-Native Speakers of English[19]

As a STEM instructor, you are likely to encounter many international students in your career. Their levels of English fluency will vary. Some may have spoken English in school from a young age, while others may be new to the language. English is relatively challenging to learn, and some students will have difficulty with it. We offer the following table as a teaching guide for instructors.

Teaching Strategies Chart[20]

	EASIER STRATEGIES	MODERATE STRATEGIES	ADVANCED STRATEGIES
CRITERIA	Don't assume lack of comprehension simply because a student's spoken English is heavily accented, or assume high levels of comprehension simply because of oral fluency. Get to know the students.	Be aware of the difference between the student who makes a variety of grammatical or lexical errors and the one who makes the same kind of error often.	Point out the most prevalent error pattern and ask the student to concentrate on that pattern when editing.
LECTURE	Highlight key points and articulate them in more than one way. Write key terms on the board or overhead. Give students breathing room by illustrating key points anecdotally rather than packing too many ideas and factual support into your presentation.	Provide written handouts for key ideas and instructions. Vary presentation methods and forms of student-teacher interaction. Supplement oral presentations with visual material.	Build rhetorical and actual questions into lectures. Supplement visual with oral information and vice versa. Supplement exposition with interactive exchange of information.
READING	Check reading comprehension by giving short writing assignments – abstracts, brief summaries, and brief responses to text. Regularly read student writing and clarify concepts and facts for students who have repeated difficulty.	Help students understand how to use the dictionary strategically for field specific and frequently used academic terms. Provide study questions or lists of key terms. Ask students to identify terms or concepts they think are unclear.	Have students write about passages of text that don't make sense or that seem contradictory to them. Illustrate how word form affects the meaning of key terms and concepts.
DISCUSSION	Periodically review and ask questions about main points. Be sensitive to the reluctance of students to speak voluntarily.	Have students write and talk in small groups before asking them to articulate answers to interpretive and sophisticated questions in whole-class discussion.	Imagine the ways that students are likely to experience confusion and ask questions that will illustrate the potential for confusion in the material.

	Acknowledge the difficulty of some concepts.		
PAPERS	Encourage students to share rough drafts with you and focus first on content, not grammatical error or stylistic weakness.	Suggest ways to improve drafts by separating issues of organization and content from issues of language error. Encourage language improvement by noting one or two most pervasive errors at the word or sentence level.	Address key problems with comprehensibility, pointing out the elements that create confusion for you as a reader. Encourage self-editing with a focus on pervasive patterns of error.
STRUCTURE	Encourage students to come to office hours by bringing a sign-up sheet. When returning an assignment, issue a written invitation to see you.	Allow students to do oral presentations (at least the first one) in groups or pairs, and build in practice time. Offer review sessions before exams.	Offer a variety of group work opportunities. Let students select tasks that emphasize their strengths.
ASSESSMENT	When writing questions, express them in simple, clear language, avoiding confusing constructions such as double negatives. Emphasize the value of authentic work and redrafting or editing.	Assess students' comprehension early in the quarter and frequently. Provide instructive comments on written assignments and invite those who are having trouble to make an appointment to see you.	Ask students to submit all drafts of work to you with editors', tutors', and your comments visible to assure work is their own.

Creating a Learning Environment[21]

Recognize any biases or stereotypes you may have absorbed.

Do you interact with students in ways that manifest double standards? For example, do you discourage women students from undertaking projects that require quantitative work? Do you undervalue comments made by speakers whose English is accented differently from your own? Do you assume that most African American, Chicano/Latino, or Native American students on your campus are enrolled under special admissions programs? Do you assume that most students of color are majoring in ethnic studies?

> *Be aware of the fact that comments that are not fully explained may inadvertently invoke stereotypes or promote inaccurate conclusions.*

Be careful about the comments made during class lectures, discussions, recitation sessions, etc. Be aware of the fact that comments that are not fully explained may inadvertently invoke stereotypes or promote inaccurate conclusions. Similarly, skewed examples of religious, historical, or other events have the potential to lead students to believe that inaccuracies are truths.

Treat each student as an individual, and respect each student for whom he or she is.

Each of us has some characteristics in common with others of our gender, race, place of origin, and cultural group, but these are outweighed by the many differences among members of any group. We tend to recognize this point about groups we belong to ("Don't put me in the same category as all those other New Yorkers/Californians/Texans you know"), but sometimes fail to recognize it about others. However, any group label subsumes a wide variety of individuals – people of different social and economic backgrounds, historical and generational experience, and levels of consciousness.

Try not to project your experiences with, feelings about, or expectations of an entire group onto any one student. Keep in mind, though, that group identity can be very important for some students. College may be their first opportunity to experience affirmation of their national, ethnic, racial, or cultural identity, and they may feel both empowered and enhanced by joining monoethnic organizations or groups (Institute for the Study of Social Change, 1991).

Rectify any language patterns or case examples that exclude or demean any groups.

Do you:

- ☑ Use terms of equal weight when referring to parallel groups: men and women rather than men and ladies?
- ☑ Use both he and she during lectures, discussions, and in writing, and encourage your students to do the same?
- ☑ Recognize that your students may come from diverse socioeconomic backgrounds?
- ☑ Refrain from remarks that make assumptions about your students' experiences, such as "Now, when your parents were in college…?"
- ☑ Refrain from remarks that make assumptions about the nature of your students' families, such as "Are you going to visit your parents over spring break?"
- ☑ Avoid comments about students' social activities that tacitly assume that all students are heterosexual?
- ☑ Try to draw case studies, examples, and anecdotes from a variety of cultural and social contexts?

Do your best to be sensitive to terminology.

In general, you should consider whether using age, gender, ethnicity, or sexual orientation is necessary or relevant to your point — it rarely is. Terminology changes over time, as ethnic and cultural groups continue to define their identity, their history, and their relationship to the dominant culture. To find out what terms are used and accepted on your campus, you could raise the question with your students, consult the listing of campus-wide student groups, or speak with your faculty affirmative action officer.

In the 1960s, for example, the term "Negro" gave way to "Black" and "Afro-American." In the 1990s, the term "African American" gained general acceptance. Most Americans of Mexican ancestry prefer "Chicano" or "Latino" or "Mexican American" to "Hispanic." Asian Americans may be offended by the term "Oriental," which connotes British imperialism; and many individuals want to be identified not by a continent but by the nationality of their ancestors, for example, "Thai American" or "Japanese American." In California, "Pacific Islander" and "South Asian" are currently preferred by students whose forebears are from those regions.

The term "sexual orientation" is preferred to "sexual preference." In addition, use the adjectives "lesbian" or "gay" to describe someone, instead of referring to them as "homosexual," and refer to a lesbian or gay couple as "partners" or "spouses," rather than "husband and wife."

Get a sense of how students feel about the cultural climate in your classroom.

Let students know that you want to hear from them if any aspect of the course is making them uncomfortable. During the term, invite them to write you a note (signed or unsigned) or to answer one or more of the following questions on mid-semester course evaluation forms (adapted by Davis from Cones, Janha, & Noonan, 1983):

- Does the course instructor treat students equally and evenhandedly?
- How comfortable do you feel participating in this class? What makes it easy or difficult for you?
- In what ways, if any, does your ethnicity, race, or gender affect your interactions with the teacher in this class? With fellow students?

Become more informed about the history and culture of groups other than your own.

Avoid offending out of ignorance. Strive for some measure of "cultural competence." Know what is appropriate and inappropriate behavior and speech in cultures different from your own (Institute for the Study of Social Change, 1991). Border and Chism (1992) provide a reading list, organized by ethnic groups, on multicultural teaching in colleges and universities. Beyond professional books and articles, read fiction or nonfiction works by authors from different ethnic groups. Attend lectures, take courses, or team-teach with specialists in ethnic studies or women's studies. Sponsor mono- or multicultural student organizations. Attend campus-wide activities celebrating diversity or events important to various ethnic and cultural groups. If you are unfamiliar with your own culture, you may want to learn more about its history as well.

Convey the same level of respect and confidence in the abilities of all your students.

Research studies show that many instructors unconsciously base their expectations of student performance on such factors as gender, language proficiency, socioeconomic status, race, ethnicity, prior achievement, and appearance (Green, 1989). Research has also shown that an instructor's expectations can become self-fulfilling prophecies: students who sense that more is expected of them tend to outperform students who believe that less is expected of them – regardless of the students' actual abilities (Green, 1989; Pemberton, 1988). Tell all your students that you expect them to work hard in class, that you want them to be challenged by the material, and that you hold high standards for their academic achievement. And then practice what you have said: expect your students to work hard, be challenged, and achieve high standards (Green, 1989; Pemberton, 1988).

Don't try to "protect" any group of students.

Don't refrain from criticizing the performance of individual students in your class on account of their ethnicity or gender. If you attempt to favor or protect a given group of students by demanding less of them, you are likely to produce the opposite effect: such treatment undermines students' self-esteem and their view of their abilities and competence (Hall & Sandler, 1982). For example, one faculty member mistakenly believed she was being considerate to the students of color in her class by giving them extra time to complete assignments. She failed to realize that this action would cause hurt feelings on all sides: the students she was hoping to help felt patronized and the rest of the class resented the preferential treatment.

Don't refrain from criticizing the performance of individual students in your class on account of their ethnicity or gender.

Be evenhanded in how you acknowledge students' good work.

Let students know that their work is meritorious, and praise their accomplishments. But be sure to recognize the achievements of all students. For example, one Chicana student complained about her professor repeatedly singling out her papers as exemplary, although other students in the class were also doing well. The professor's lavish public praise, though well intended, made this student feel both uncomfortable and anxious about maintaining her high level of achievement.

Recognize the complexity of diversity.

At one time the key issue at many colleges was how to recruit and retain African American students and faculty. Today, demographics require a broader multicultural perspective and efforts to include many underrepresented groups. Although what we know about different ethnic groups is uneven, avoid generalizing from studies on African American students.

Introduce discussions of diversity at department meetings.

Concerned faculty can ask that the agenda of department meetings include topics such as classroom climate, course content and course requirements, graduation and placement rates, extracurricular activities, orientation for new students, and relations with the English as a second language (ESL) program.

Dealing with Disruptive Behavior in the Classroom[22]

Prevention

The best place to start when seeking to develop a positive learning environment, of course, is to try to prevent disruptive behavior in the first place; however, this is only partially under your control. Here are some suggestions:

- Include course and behavior norms and expectations for students and instructors in your syllabi.
- Discuss these norms and expectations on the first day of class. Tell students you expect that they will act appropriately, but that you want to remind students of these norms.
- Share control and responsibility with students in the class by asking them on the first day what the norms for classroom behavior should be, and adding their ideas to your list.
- Draw up a "contract" for classroom behavior and ask students to read and sign it the first week of class (this can include that they agree to attend class, participate, be prepared, etc.).
- Be extra tough on all matters the first day and week to set the "tone." You can always be flexible and nurturing later.

Intervention

If disruptive behaviors occur despite your efforts at prevention, you must act as early/quickly as possible. Otherwise, you can "lose control" of the classroom, frustrate other students, and create a hostile learning environment.

Mild Classroom Interventions

- Walk over to talkative students and conduct class standing right next to them.
- Direct firm, but not derogatory, comments to the disruptive students during class. Ask if they have a comment or question. Ask them to be quiet. Let them know they are being unfair to their peers.
- On a given day when this behavior occurs, change what you are doing. Break students into groups for some work. Call on these and other students to come forward and lead discussion.
- Stop whatever you are doing and wait (as long as it takes) for students to quiet down while you look at the disruptive students. Then begin again.

More Extreme Classroom Interventions

- Spend some time in class discussing the whole situation openly and honestly with all the students. What do they think? Tell them how you feel. Ask how they think things should be handled. You may feel you cannot "waste" class time doing this. But, if class time is disrupted by students and this affects your ability to work, learning is being harmed and the class time is already being wasted.
- Ask the disruptive student(s) to leave the classroom for that class period.
- Consider changing the structure of the whole class. Is it all lecture? Do students need to be more active and involved? Rethink if/how what you do fits the students and the course. Use more diverse techniques to reach the disruptive student(s).

Out-of-Class Interventions

- Talk with colleagues in your department (including your chair). How would they handle these situations? What do they see as normative? This gives you ideas for handling the situation and lets your chairperson know what is happening early on, and that you are trying to deal with it.
- Note who the disruptive students are and speak to them after class or ask them to come to your office hours. Explain why/how you find them disruptive, find out why they are acting that way, ask them what they would be comfortable doing. Tell them what you want to do.
- Discuss the disruptive behavior in private outside of class with some of the concerned and non-disruptive students. Ask for their assistance in maintaining a positive classroom environment.
- Inform the student outside of class that their disruptive behavior does not fit your criteria for participation and that their grade will be lowered if it does not

stop (this one can be tricky, depending on what your syllabus says and how you handle it).

Balancing Discipline and Student Evaluations

Finally, concern about students' reactions and negative feedback on student evaluations as a result of these types of situations is often an issue for faculty. Overall, these situations will probably not have a major impact on your evaluations. In addition, the fact that you have tried to address these situations and deal with the disruptive students should further reduce any negative effects. Discussing the problem openly with students may also help.

Common Disruptive Student Behaviors and Possible Responses[23]

The following are examples of student behaviors that have the potential to disrupt class or successful learning, along with several possible responses.

Rambling — wandering around and off the subject. Using far-fetched examples or analogies.

- Refocus students' attention by restating a relevant point.
- Direct questions to a group that is back on the subject.
- Ask how the topic relates to the current topic being discussed.
- Use visual aids, begin to write on the board, turn on an overhead projector.
- Say: "Would you summarize your main point please?" or "Are you asking...?"

Shyness or Silence — lack of participation.

- Change your teaching strategies from group discussion to individual written exercises.
- Give strong positive reinforcement for any contribution.
- Involve the shy student by directly asking him/her a question.
- Make eye contact with the student.
- Appoint the student to be small group leader.

Talkativeness — knowing everything, manipulation, chronic whining.

- Acknowledge the comments.
- Give the student limited time to express his or her viewpoint or feelings, and then move on.

- Make eye contact with another participant, and move toward that person.
- Give the person individual attention during breaks.
- Say: “That’s an interesting point. Now let’s see what other people think.”

Sharp-shooting — trying to shoot you down or trip you up.

- Admit that you do not know the answer and redirect the question to the group or the individual who asked it.
- Acknowledge that this is a joint learning experience.
- Ignore the behavior.

Heckling/Arguing — disagreeing with everything you say; making personal attacks.

- Redirect the question to group or supportive individuals.
- Recognize the participant's feelings and move on.
- Acknowledge positive points.
- Say: “I appreciate your comments, but I’d like to hear from others,” or “It looks like we disagree.”

Grandstanding — getting caught up in one’s own agenda or thoughts to the detriment of other learners.

- Say: “You are entitled to your opinion, belief or feelings, but now it's time we moved on to the next subject,” or “Can you restate that as a question?” or “We’d like to hear more about that if there is time after the presentation.”

Overt Hostility/Resistance — angry, belligerent, combative behavior.

- Hostility can be a mask for fear. Reframe hostility as fear to depersonalize it.
- Respond to the fear, not the hostility.
- Remain calm and polite. Keep your temper in check.
- Don’t disagree, but build on or around what has been said.
- Move closer to the hostile person; maintain eye contact.
- Always allow him or her a way to gracefully retreat from the confrontation.
- Say: “You seem really angry. Does anyone else feel this way?” Solicit peer pressure.
- Do not accept the premise or underlying assumption, if it is false or prejudiced; e.g., “If by ‘queer’ you mean ‘gay’...”

- Allow the individual to solve the problem being addressed. He or she may not be able to offer solutions, and will sometimes undermine his or her own position.
- Ignore the behavior.
- Talk to the student privately during a break.
- As a last resort, privately ask the individual to leave class for the good of the group.

Griping — may be legitimate complaining.

- Point out that you can't change the policy.
- Validate the student's point.
- Indicate that you'll discuss the problem with the participant privately.
- Indicate time pressure.

Side Conversations — may be related to subject or personal. Distracts classmates and you.

- Don't embarrass the talkers.
- Ask their opinion on the topic being discussed.
- Ask the talkers if they would like to share their ideas.
- Casually move toward those talking.
- Make eye contact with them.
- Comment on the group (but don't look at them individually).
- Standing near the talkers, ask a nearby participant a question so that the new discussion is near the talkers.
- As a last resort, stop and wait.

Dealing with Apathetic Students[24]

Some students demonstrate what Paulos (1988) calls extreme intellectual lethargy. These students seem to be so lacking in mental discipline or motivation that nothing can get through to them. Faculty members have described this group as having an "I dare you" attitude, as being indifferent at best and hostile at worst.

Sometimes this behavior masks fear or poor preparation. Sometimes it signals a short attention span. It also may indicate a more serious systemic problem such as attention deficit disorder. Faculty members may want to refer these students to college or community services designed to assist them. Catching and holding the interest of these students in class requires patience, perseverance, and ingenuity:

- Call on a specific student.
- Ask the student for a counter example, doubt, or criticism relating to your presentation or argument.
- Ask students to confer and to report on agreements and disagreements. Use this opportunity to call specifically on disaffected students.
- Ask the student to participate in a laboratory or classroom demonstration.
- To aid those with shorter attention spans, break class periods into segments with changes in presentation strategy and level of student activity, and switching of student roles (between questioning, note taking, reflecting, discussing, challenging, and summarizing).
- Invite the student to come in for a conference to discuss how the course and the student's attitude might be improved.

Cultural Differences for International Instructors[25]

U.S. students grow up hearing a lot of praise when they do things well, even simple things like answering a question correctly. You would do well to follow this pattern to build a warm atmosphere in the classroom and to encourage students to volunteer responses to your questions and to be comfortable asking about things during class.

Adjusting to Informality and Asserting Authority

U.S. students behave less formally toward their teachers than students of many other countries do. As an instructor, you may interpret your students' casual dress or snacking in class as signs of disrespect. You may be surprised to be addressed by your first name. Although you may think that the students do not like you because of their casual attitude, this conclusion is not necessarily true. U.S. students behave this way in classes taught by teachers they like very much as well as by those they do not like. What you may perceive as a lack of respect may be their egalitarian attitude toward authority figures.

> *What you may perceive as a lack of respect may be [an] egalitarian attitude toward authority figures.*

Occasionally, instructors interpret the informality of U.S. students as an indication that "anything goes" in class. This is not true. Students who interfere with the normal functioning of the class must not be allowed to behave that way. You are within your rights to ask them to either stop what they are doing or leave. Ask for help in dealing with discipline problems from other faculty in your department who are experienced teachers. If you present a confident image of yourself as an instructor well prepared for the course, you will probably not face many discipline problems. If students see that you have both a good grasp of the subject matter and faith in your ability to teach, they are likely to respect you. If you are organized and can keep them engaged in thinking and participating in the class, they won't have time to create problems.

Developing Rapport

U.S. students expect and appreciate instructors who treat them in a friendly manner (e.g., addressing them by name, smiling, and showing enthusiasm for the class). Students often speak approvingly of teachers who "made the class interesting," which might include occasionally joking with them and using imaginative examples when you are explaining something complex and abstract. Before class begins or when it is finished, you can engage in some "small talk."

Find out something about your students' lives and use them as resources of information. Learn your students' first names (or nicknames) and something about each, if possible. Because Americans have come from so many other countries, last names may be difficult to pronounce and present a challenge to anyone calling the roll for the first time. Do not spend too much time on last names; at first it may be easier to pass around an attendance sheet for everyone to sign rather than reading names aloud. A seating chart is one way to be able to learn names and to call on students. Handing back homework assignments is another way to connect names (and awareness of students' abilities) with faces. If you are able to greet your students by name when you see them walking around campus, you may be held in high regard.

Above all, treat your students fairly and show them you are concerned with their success in your class. Be explicit about test and project dates and how grades are earned and given. Treat their questions as genuine requests for information and not as tests of your knowledge or challenges to your authority; Americans have been raised to ask questions whenever they don't understand something. If their question is off the subject, tell them nicely that you can talk to them later about it instead of taking class time. Avoid sounding angry or defensive, and do not completely ignore the question. If it is something you do not want to answer, you can always say something like "That's a question for another day. Today we have got to stick to the topic of X or we are going to get behind the other sections, and I won't get through all the material you need for the exam."

Americans have been raised to ask questions whenever they don't understand something.

Grade Consciousness

U.S. students are extremely grade conscious. Speaking about an exam normally wakes up the whole class. Not only do they want to know when the tests will be and what material will be covered, they will ask you to describe in detail what they need to study, whether the test will be essay or multiple choice, how it will be graded, and how much time they will have. They will also ask many questions about term papers and homework assignments.

Sexual Harassment

Many instructors who are unfamiliar with male-female relationships in the U.S. are concerned about what behavior might trigger a charge of sexual harassment. Find out what your school's policy on sexual harassment is; usually, this information can be found on the school's Web site.

Summary of Addressing Students' Needs

- ☑ Ask for background information from your students regarding their prior educational experience, any special assistance/accommodations, etc. as soon as possible.
- ☑ Consider differences in gender, age, religion, race, language, education and ability when preparing reading/lecture materials and while talking to students.
- ☑ Hold the same expectations for all of your students, regardless of their age, gender, religion or race.
- ☑ Recognize the differences between you and your students in terms of culture or religion, and become more informed about their cultures and practices.
- ☑ When dealing with disruptive students, maintain your composure and control in the classroom, and minimize the effect the disruption has on other students. Try to ignore or minimize the disruption until you can deal with the student alone outside of class.

Teaching Tips

Organizing Class[26]

N. L. Gage (1976), director of research and development in teaching at Stanford University, formulated six characteristics of effective presentations. He found that successful college instructors:

- ☑ *State objectives* at the beginning of a lesson
- ☑ *Outline* the lesson content
- ☑ *Signal transitions* between parts of a lesson
- ☑ *Point out important points* in a lesson
- ☑ *Emphasize concepts* interrelating from different parts of the lesson
- ☑ *Summarize* the parts of the lesson as the lesson proceeds
- ☑ *Review main ideas* and facts covered in a lesson at the end of a lesson and at the beginning of the next lesson. Give these cues in your writing; give them in class, too.

Be aware that not all lessons proceed as planned, and allow some class time for various unexpected happenings. Instructional skill takes time to develop, as does any valuable talent. Work on one, or at the most, two skills each week.

Ways to Be Accessible Outside the Classroom[27]

- Arrive at class ten minutes early and stay ten minutes after to give students a chance to talk to you.
- Set office hours and keep them; nothing is more frustrating for a student than to take the time to seek out a teacher's office and then find that the teacher is not there. If you must cancel your office hours, notify your students in advance and tell them why (you need not be too specific). If you cannot notify them in advance, then be sure to post a note on the office door. Also, be sure to provide alternate hours if possible.
- Always leave your office door open when meeting with a student. This makes it difficult for you to be accused of inappropriate conduct or to be threatened in any way.
- Allow students to make an appointment to talk with you at a different time. Remember your office hours will not be convenient for all your students. Provide students with your office phone number or e-mail address if you have one.

- Provide your home phone only if you are comfortable with releasing this information to your students. Remember, you are under no obligation to provide off-campus contact information to your students. And never give students your home address.
- Ask students for a phone number or e-mail address where you can reach them in case it is necessary to cancel class. Remember, it is the students' right not to give you this information.

Six Common Non-Facilitating Teaching Behaviors[28]

Many instructors unwittingly behave in ways which not only frustrate their own goals, but also actively discourage significant (as opposed to rote) student learning. The relationship between teachers' behaviors as perceived by their students and the quality and quantity of students' learning, motivation, and student-teacher communication is amply documented in the research literature (Amidon & Hough, 1967; Flanders, 1970). In this author's experience observing teachers' behaviors in elementary, secondary and university classrooms, both in person and on videotape, certain non-facilitating behaviors have become vivid through their very repetition.

At issue is the relationship between intent and actions: what teachers do and how they do it delivers more of an impact than what they say. Within the body of this paper, six common non-facilitating teacher behaviors will be defined, exemplified, and discussed.

1) Insufficient "Wait-Time"

Students who note that their instructor answers a preponderance of his own questions without waiting for a response soon grow dependent upon the teacher to do their thinking for them.

"Wait-time" is the amount of time after an initial question has been posed before the teacher answers it, repeats, rephrases, or adds further information to the question; or accepts an answer from a student.

More than just a few seconds are necessary for mental information-processing (Moriber, 1971; Rowe, 1974). When the teacher becomes a nonstop talker, filling every possible silence with his voice, what chance do students have to think over what is being said, formulate intelligent responses, or ask for clarification?

Mental information-processing may be accompanied by verbal analyses or proceed in silence. It does seem logical, therefore, that if the facilitation of students' learning is of paramount importance, then teachers should allow for individual differences in learning style by providing a modicum of quiet time for thinking as well as opportunities for verbal responses.

Students who note that their instructor answers a preponderance of his own questions without waiting for a response soon grow dependent upon the teacher to do their thinking for them. In like manner, an answer too rapidly accepted has the effect of cutting off further information-processing and analysis by the rest of the class. Instructors may attest verbally to their aim of encouraging independent thinking, but unless they consciously work to expand their wait-time, they will have rhetoric with little resultant change in behavior.

Rowe (1974) reported that when teachers were trained to increase their wait-time from one second to 3-5 seconds, several changes occurred in students' behavior: the length and number of unsolicited but appropriate responses increased, the number of failures to respond decreased, and the incidence of student-to-student comparisons of data increased. Instructors who are interested in repeating this experiment in their own classrooms can measure their wait-times ("one, one-thousand; two, one-thousand," etc., sufficing for timing purposes) and then deliberately expand these periods of silence-for-thinking both after a question is posed and after an answer has been given. Sharing the concept of wait-time for thinking with the students often enables the teacher to maximize his efforts and gives the class an insight into learning skills.

2) The Rapid-Reward

Consider the effect on students' processing of information and analysis of data when an instructor says immediately to the first respondent to his question: "Right, good." As if to assure that further thinking will be terminated, the teacher either proceeds to re-word, repeat, and exemplify the answer, or goes on to the next topic. Learning being a highly individual process, people learn at different rates and in varying ways. Rapid acceptance of a correct answer favors the faster thinker/speaker who has completed his thought processes; those in mid-thought have their answers terminated prematurely.

Rapid acceptance of a correct answer favors the faster thinker/speaker.

A variation on this theme is the softly-voiced, hesitant answer of the student seated nearest the instructor. Because many students commonly respond softly to the teacher if he is within close proximity, an awareness of the consequences of this behavior is crucial. Many a student seated out of earshot has become frustrated, bewildered, or disinterested when a softly-voiced, difficult-to-hear answer is rapidly rewarded. To ameliorate this situation, encourage student-to-student dialogue, discussion, and peer critiquing of ideas. The following are suggested: extended silent time after an answer is offered; a questioning glance around at other students, tacitly requesting comment; a question to those in the rear, "What is your analysis of what was just said?" and, most important, physical movement of the teacher from place to place about the room in order that as many students as possible enjoy close proximity to the instructor, or "front row seats," at one time or another during the class.

3) The Programmed Answer

The following are examples taken verbatim from classroom dialogues and best exemplify this third non-facilitating teaching behavior.

- "What are some of the enemies of the praying mantis? Cats kill them, don't they? How about other animals? Or insects?"
- "What reasons do you have to use that formula? Was it suggested in the homework chapter? Had you ever used it before? Or seen it used in this context?"
- "What happens when we add the sums of the rows? Do we get skewed results?"
- "Look at this shrub and tell me, what observations can you make? Do you see the dead stems? Are they damaged from insect feeding?"

The programmed answer not only deprives the respondent of expressing his own thoughts by steering him toward the answers that the questioner expects, but also conveys the message that there is really little interest in what he thinks or says. While the reasons offered by those who make a practice of this pattern are usually altruistic (i.e., "Silence after the posing of a question is embarrassing to the student;" "I feel impelled to help out by suggesting clues"), one needs to ask oneself honestly: "Is it I or the student who is uncomfortable after a second or two of silence?"; "Do I have confidence in the students' ability to think about the question and formulate a response?"; and, more importantly, "Am I interested in what the student has to say, or in determining which of my answers he prefers?" While programming can be an effective tool when one desires to guide students' thinking, suggest possibilities, or model logical thought processes, it is important to be aware of its limiting effect in opening up a wide variety of possible ideas. It is via the latter route that an instructor can demonstrate his interest in the students' ideas and himself model inquisitive learning behavior. A willingness to listen helps to create in the classroom a community of learners in place of an authoritative, superior-subordinate relationship between teacher and class.

4) Non-Specific Feedback Questions

Many instructors feel justified in assuming that their students have no questions if no one responds when they ask, "Are there any questions? Do you all understand?" Purportedly designed to give the instructor information as to the clarity and comprehensibility of his presentation, these questions usually fail to solicit feedback. Why? We can isolate several possibilities, two of which are the nature of students and the nature of the questions.

What type of student will bravely call attention to his own ignorance when the question is posed to a class: "Does everyone understand?" Interestingly enough, it was a student who suggested that those who do respond comprehend most of the concept, lesson, problem, etc., and need only a minor point made clear. Others, whose lack of understanding is more comprehensive, whose confusion is more widespread, may be too intimidated to call attention in such a public way to their situation. Often, the latter are so confused that they cannot think of questions to ask. Yet these are the students who most need assistance. How can instructors determine what it is they do and do not understand?

Contrast the following pairs of questions:

A. "Does anybody have any questions?"
B. "Let's think of some other examples now of situations in which this principle is applicable."

A. "Does everybody see how I got this answer?"
B. "Why did I substitute the value of x in this equation?"

A. "Who wants me to go over this explanation again?"
B. "What conclusions can we generalize from this specific graph?"

You need to ask yourself, "What do students need to say or do for me to determine the extent of their understanding?" You can then formulate and pose one or several specific questions, which will give a more comprehensive sounding of the class's problems, and questions.

5) The Teacher's Ego-Stroking and Classroom Climate

Think of the effects on students' willingness to respond to teacher-posed questions when statements such as the following are made:

- "Since I have explained this several times already, you all should know what is the effect of an increased demand upon this supply curve."
- "Obviously, when you use this formula you'll get…?"
- (After having listened to several students' answers) "The real answer is this:"
- "Does everybody understand the explanation I just gave? It should be clear by now."
- "O.K. Now rephrase your answer the way you think I would say it."

> *Your behavior is an important determinant in the establishment of a safe or comfortable climate.*

Students need to feel that it is psychologically "safe" to participate, to try out ideas, to be wrong as well as right. Your behavior is an important determinant in the establishment of a safe or comfortable climate. Learning, an active process, requires that the learner interact with ideas and materials. Constant teacher-talk, feeling compelled to comment on each student idea, deciding to be the final arbiter in decision-making processes, interrupting, controlling, and intimidating either through expertise, or the threat of grades – these are but some of the behaviors which prevent students from engaging in the active processes needed for significant (as distinguished from "rote") learning to take place. It is interesting to note the increased levels of student participation when instructors do not conceal the fact of their ignorance, when they sometimes hesitate about certain questions or information, when their responses are dictated more by an honest desire to assist the students than to demonstrate the extent of their own knowledge.

A few of the possible behaviors which can encourage the establishment of an environment conducive to participation are:

- Remembering and referring to students' ideas
- Yielding to class members during a discussion
- Acknowledging one's own fallibility
- Framing open-ended questions which allow expressions of opinion and personal interpretations of data
- Accepting the students' right to be wrong as well as correct
- Encouraging joint determinations of goals and procedures when feasible (e.g., "How can I help you best to learn this material?")
- Sharing the responsibility for learning with the learners (i.e., permitting students to answer their peers' questions)
- Freeing oneself from the burden of thinking that students cannot learn elsewhere what isn't covered in class
- Encouraging group presentations of the material to be covered
- Soliciting student participation in their own learning assessment such as developing test questions and jointly correcting examinations

Questioning can be a central feature in promoting the development of conceptual abilities, analytical techniques, and the synthesis of ideas.

6) Fixation at a Low Level of Questioning

Bloom (1956) has postulated that cognition operates on ascending levels of complexity. One begins with knowledge, or informational details, and moves upward through comprehension, analysis, and synthesis to evaluation. Questioning can be a central feature in promoting the development of conceptual abilities, analytical techniques, and the synthesis of ideas. Skillful teachers use questions to guide thinking as well as to test for comprehension. Too often, however, as illustrated by this sixth recurring pattern, teachers' questions become fixated at the informational level, requiring of students only that they recall bits and pieces of rote-memorized data:

informational-level questions. For example, asking, “What is the formula for finding the force between two charges?” or “What is the definition of ‘quantity demanded?’”

One-word or short-phrase answers, those capable of being sung out in unison, constitute the preponderance of question-and-answer dialogues in many classrooms and necessitate little interrelating of material, sequencing of thoughts, or analyzing of data. While a solid base of factual information in learning is clearly important, fixating students’ thinking at this level discourages the development of more complex intellectual skills. Questions can encourage the students to use informational knowledge to analyze concepts, synthesize complex relationships, and evaluate the new data. For instance, ask, “What would happen if we inserted a metal conductor in between the moving charge and the current?” or “Why must the information in Table One change when we consider these new data?”

Being conscious of the levels of questions one is asking and attempting to structure the questions toward analysis, synthesis, and evaluation can do much to combat fixation at the informational level of thinking.

Conclusion

If asked to formulate the goals of the educational process, most teachers would include the nourishment of intellectual curiosity, encouragement of independent learners, and development of more complex thinking processes. Yet instructors’ behaviors such as the six described in this paper militate against the achievement of these goals.

Those who sincerely desire to examine and analyze their own teaching behaviors face a problem – the evanescence and multi-dimensional aspects of the teaching-learning relationship. Capturing the classroom behaviors of teachers and students on closed-circuit television with instant-replay features offers one solution. Utilizing such criteria as the six patterns described in this paper – insufficient wait-time, the rapid-reward, the programmed answer, non-specific feedback questions, the teacher’s ego-stroking and classroom climate, and fixation at a low-level of questioning – teachers can analyze their own behaviors and examine the effects of their actions on student learning. Such self-analysis can be the beginning of behavioral change.

Wireless in the Classroom: Advice for Faculty [29]

You may be teaching a large lecture and look out into your audience and see 10 or 20 students using laptops. Some may be using them to take notes, while others may have needs which require adaptive technology such as a laptop to perform well in a classroom setting.

The following are some strategies to help you set expectations and reduce distractions:

Set Ground Rules for Wireless Use in the Classroom

A few ground rules may make for a better experience in a wireless-enabled classroom. Here are some suggested guidelines; modify them to suit your needs.

- Set a "no laptop time." Have periods during class where laptop users must close their lids.
- Note: special needs students may require exceptions to this rule; ask them to discuss these needs with you.
- State that laptop use and cell phone use are prohibited during test times.
- Establish consequences for inappropriate laptop use, just as you would for cheating.
- Encourage your students to be mindful of how they use their laptops. Empower them to stop inappropriate use (such as viewing inappropriate web sites) by speaking directly to their peers.

Establish Laptop Etiquette

A few stated standards of laptop etiquette given at the beginning of class (with periodic reminders) may help to foster a positive environment.

- Be sure your sound is off at the beginning of class.
- Stay on task. Activities such as surfing or gaming may be a distraction to classmates.
- Observe all "laptop prohibited" times.
- Listen to your classmates if they complain that your use is distracting.

Best Practices for Using Wireless in Teaching

Here are more suggestions for getting the best experience out of teaching in a wireless-enabled classroom.

Instructing

1. Laptops and other e-learning strategies appear to be most effective when they are used in combination with teaching methods that rely on increased student participation. The key is to create active learning opportunities, and not to resort to passive learning methods.
2. Have a screen-up and screen-down time.
3. Consider walking into the audience periodically.

4. Make sure you are well-versed in the software that you are going to use. Have a backup plan in case the technology fails.

Interacting

1. Use laptops to recording the activities of team projects in class.
2. Increase your student-to-student and student-to-teacher interactions to support a more active learning approach.
3. Have a good mix of in-class and out-of-class activity, and interweave the two so each is present in each setting.

Improving

1. Seek feedback from your students.
2. Consider pursuing a scholarly investigation of the changes you make. Collaborate and share your discoveries.
3. Take time out to reflect on your own progress in creating a meaningful learning experience.

Summary of Teaching Tips

- ☑ Get students to interact with each other and with you as much as possible through questions and discussion.
- ☑ Have students reflect on class material by doing short writing exercises, explaining concepts to other students, and creating possible exam questions.
- ☑ Maintain an open dialogue with your students by encouraging them to ask questions and getting feedback (written or orally) from students frequently.
- ☑ When asking students questions about materials or concepts, or after a student answers a question, wait five seconds for students to reflect before moving on.
- ☑ Summarize the main ideas of your lesson before and at the end of class, signal transitions between different topics/ideas, and point out how concepts interrelate to one another.
- ☑ Ask open-ended questions that allow students to respond with their own ideas, and respond to students' answers with specific questions (e.g., instead of "Does anyone have any questions?," try "What are some other examples of x that use this same principle?").

Part Two:
Teaching Methods

Part Two: Teaching Methods

This section of *Reaching All Students* offers you a broad array of tips from professors at many universities. Beginning on the first day of class, this section includes strategies for the new professor and teaching assistant, as well as insights for the seasoned veteran.

Topics include:

- how to lecture dynamically in even the largest classrooms,
- how to facilitate dialogue both in a discussion section and in the general classroom, how to encourage effective group work, how to oversee a lab section – and finally,
- how to connect with students beyond the classroom.

In every context, it is possible to develop a collaborative and constructive learning environment. In this way, you may include all students.

Many capable students drop out of the science, technology, engineering, and mathematics (STEM) disciplines. This problem is particularly relevant to students from underrepresented groups in STEM. Creating an environment that is challenging and encourages all students requires use of a variety of teaching strategies (e.g., lecture, group discussion). Effective teaching that treats every member of the class as a unique and important individual will go a long way to solving problems of retention, and will increase student learning.

The First Day of Class

When the Class Meets You[30]

The first day of class is when you introduce yourself to your students. Clearly spell out the relationship you want to have with students (e.g., see me during office hours and by appointment; see me any time; here's my e-mail address) and let your students know how you want to be addressed. You need to accomplish a number of administrative tasks while trying to create an open, welcoming classroom environment. Focus on setting course expectations and standards. Let students know you have high expectations for them, but that you are committed to helping them reach those goals.

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When to Arrive

The timing of your arrival on the first day of class will help set the tone for the semester. If you arrive early, well before class begins, you can get to know students and they can get to know you. If you want a more formal setting, you can arrive just before you are about to begin class, without leaving time for informal discussion.

What to Post on the Board

It is usually a good idea to arrive at least a few moments before class begins to give yourself time to write the title of the course, the section number, your name, your office phone number, and the instructor's and/or teaching assistant's name on the board before students arrive. Then they will know whether or not they are in the right place. You could also post your office hours if you have determined them, but some instructors like to wait until they have experienced a week of their own academic schedules so they will not post what turns out to be an impossible time slot for either themselves or their students.

Let students know who you are by telling them why you chose the field you are in and why you find it exciting.

Introducing Yourself

Let students know who you are by telling them why you chose the field you are in and why you find it exciting. Tell them about relevant experiences or background that qualifies you to teach this course. Try to make yourself more approachable by giving them more of your background — telling them where you are from, where you did your undergraduate work, and other interests you may have. Furthermore, if you are making choices about the way the class is taught, you may want to provide them with a rationale for the format of the course and why you chose the teaching methods you have. This lets students know that you have thought about your teaching and how it can enhance their learning. If you have a philosophy of teaching, share that with the students. For example, tell them that "Learning is about taking ideas and turning them into ideas that make sense to you;" that there are no stupid questions; and that learning should be interesting, but also requires struggle.

When You Meet the Class[31]

Getting to Know Your Students

Learning students' names can go a long way in letting students know that you care about them as people. Although it may be difficult at first, it is well worth the effort in the long run, because it lets students know you value them as individuals. In some very large lectures, it may be impossible to learn every student's name, but even using some student names in class can still be helpful.

> *Learning students' names can go a long way in letting students know that you care about them as people.*

Sometimes instructors choose to engage their entire class in an introductory activity, not only to learn students' names, but also to have students learn more about each other. Such activities can help relieve both you and the students of first-day tensions, and can also promote a comfortable atmosphere. This is particularly important if you want students to be actively involved in discussions and in asking or answering questions. It is critical to build a sense of community in the classroom and address student concerns.

These activities often involve having students get into pairs and giving them one or two questions to ask each other. Before they start the activity, tell them that they will be expected to introduce their "partners" to the entire class after having interviewed them with the questions you have assigned. Give the students about five minutes to answer these questions (two and a half minutes per partner) and then have them make the introductions to the class. Examples of such questions follow:

- What are your name, hometown, and major field of interest?
- Tell me something unique about yourself.
- If you could be any person in the world other than yourself (living or not, real or fictional), who would it be, and why?

Tips for Learning Students' Names [32]

- ☑ Use photographs. Group three or four students in a single Polaroid shot. The act of posing for a picture breaks the ice. You can have students write their names underneath their pictures.
- ☑ Arrive for class as early as you can, and use this time to sit and talk to the students who are waiting for you to begin.
- ☑ Use name cards. For seminar classes, place name cards in front of each student. For lab courses, post students' names above their work stations.
- ☑ Use a seating chart. Ask students to sit in the same general area for the first few weeks, and block general locations within the room on a piece of paper. Write the names of students inside the appropriate blocks. During the first class meeting, ask students to write answers to some simple questions about their backgrounds, interests, and motivations on index cards. Collect the cards and use them as memory aids as roll is called or as papers and quizzes are returned.
- ☑ Find out about students' experiences in other science courses, with the particular subject matter in this course, and in prerequisite courses.
- ☑ Arrange for regular informal lunches with different small groups of students.
- ☑ Early in the course, write personalized comments on assignments returned; invite students to come by to discuss their progress.
- ☑ Require students to pick up their exams in person to discuss the outcome briefly.

Diversity the Instructor Brings to the Classroom[33]

Perceived Diversity

When we speak of diversity in the classroom, we usually focus on the diversity of the students in the room. We often forget that the teacher also brings a range of diversity issues to the classroom. Every teacher brings his or her physical appearance and culture into the room at the same time as the students do. How you look, how you speak, how you behave, and the extent to which these differ from the physical, cultural and intellectual backgrounds of your students, will have a profound effect on the interactions in your classroom. Thus you need to be aware of possible reactions among the students to your race, gender, age, ethnicity, physical attributes, beliefs and abilities. Preparing for such reactions will involve not only knowing as much as you can about your students, but also turning the mirror toward yourself.

You might identify your own attitudes toward diversity by remembering certain pivotal moments in your life. Ask yourself the following questions:

1. Recall the incident in which you first became aware of differences. What was your reaction? Were you the focus of attention, or were others? How did that affect how you reacted to the situation?
2. What are the "messages" that you learned about various "minorities" or "majorities" when you were a child? At home? In school? Have your views changed considerably since then? Why or why not?
3. Recall an experience in which your own difference put you in an uncomfortable position vis-à-vis the people directly around you. What was that difference? How did it affect you?
4. How do your memories of differences affect you today? How do they (or might they) affect your teaching?

Students who perceive the teacher as belonging to a particular racial or ethnic group and who then draw initial conclusions from that classification can affect the class atmosphere either negatively or positively from the first day. One assistant professor at the University of North Carolina faced with perceived diversity issues in the classroom puts it this way:

> "An issue that concerns me greatly has to do with issues of gender and race/ethnicity in student-teacher interaction. Although some of my students have shown respect (and even admiration) toward me as a professor and as a person, other students have challenged my authority and have openly questioned my knowledge. I wonder to what extent the combination of my gender and ethnicity colors students' perception of my teaching."

It is probably impossible to determine exactly to what extent perceptions of race, gender and ethnicity motivate such challenges to the authority of the professor. Clearly, however, such perceptions do color people's everyday assumptions.

The above quotation shows that some students can see a professor's gender and ethnic diversity as advantages. If a student does repeatedly challenge the teacher in a manner the teacher deems inappropriate, however, it may be wise for the teacher to ask the student privately to come to an office hour. There, they can discuss the possible reasons behind the student's behavior in a non-threatening and less-public place. Discussing the problem privately may prevent the possibility of a single student-teacher relationship affecting the tenor of the entire class. It will also give the student the chance to explain his or her position, thus giving the student a hearing, which may in itself defuse the situation. Showing the student that you care about his or her progress, while maintaining your professional demeanor, will make the point that you both have a professional teacher/student relationship to uphold. Listening to the student and being willing to advise him or her in a friendly manner will emphasize that relationship.

The best way to minimize the likelihood that your own perceived diversity will affect student behavior is to establish a "safe" environment in which the class can discuss both your diversity and your students' diversity. Such a safe atmosphere establishes the difference between a highly successful class and one where both teacher and students fear one another, experiencing discomfort when it comes to discussing the "real" issues. This fear can be the fear of being labeled as an outsider, or the fear of offending someone and making him or her feel unwanted in the group. Either way, fear is not a good basis on which to start any discussion.

The issue of diversity will be an important point of interest to the students you meet in your classrooms because the average 18-22 year-old student is in a stage of development where cultural identity and value orientation are being established. For the first time, students find themselves in an environment where they must form opinions on these topics without worrying about what their elders will say. For many of them, the university is the first place where they meet a wide range of people from various groups and where they leave their habitual groups behind. The university environment gives them a chance to explore these issues, and most students react well when they have the chance to reevaluate the opinions with which they grew up, and to develop independently.

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Age

TAs who go directly into graduate school and immediately start teaching are less likely to have problems relating to their students' culture than older teachers do. Younger TAs are close enough in age to have been exposed to similar television shows, music, political events and so forth. However, many young TAs fear that they will fail to command attention and respect because they are too close to their students' age. This fear usually subsides rather quickly when it becomes clear that most students respect their teachers, young or old, as long as the teachers come to class well-prepared. TAs are considerably more knowledgeable in their field than most undergraduates, and will have little trouble commanding student respect if they prepare well for class and behave respectfully toward students.

Many professors and TAs who are four or more years older than their students, however, often experience a mini-generation gap. They no longer share the same tastes in music or in clothing, and they watch different (and often fewer) television shows. Often, older teachers have considerably different views on politics and current culture than their students simply because they grew up at a different time. Such differences are not negligible. One runs the risk of seeming so old-fashioned and out-of-touch that the topic one is presenting seems "purely academic" to the students. Such attitudes arise more often in courses that meet general undergraduate requirements, since students have not chosen those courses out of personal interest in the topic.

You can more easily engage your students if you can speak to them about their culture and put the major topics of your field into the context of their lives. Here you might take the opportunity to become a student of your students by educating yourself about their experience of the world. Some knowledge of current popular culture will be a step towards learning about the students' interests. Such familiarity with their interests can mean the difference between being able to teach and interest students in your field, or presenting them with material that seems irrelevant.

Conversing with Students with Disabilities[34]

The following guidelines are general suggestions for interacting with people with disabilities. This isn't assumed to be an exhaustive list, but is rather a way for you to become more comfortable in the courtesies you extend. When talking with people with disabilities, observe who they are and do not refer to them as their disability.

Guidelines for Conversing with People Who Have Mobility Impairments:

- Consider the distance, weather conditions, and surfaces along paths of travel when giving directions.
- Do not lean on wheelchairs.
- When talking with a person in a wheelchair for more than a few minutes, place yourself at the user's eye level.
- Allow a person using a wheelchair or crutches to keep them in reach. Remember that many wheelchair users can transfer to chairs, into automobiles, or into other seating arrangements.
- Ask wheelchair users if they want to be pushed before doing so.

Guidelines for Conversing with People Who Have Visual Impairments:

- When greeting someone with a visual impairment, identify yourself and others who are accompanying you. When you are leaving the space, let the person with a visual impairment know. Being blind doesn't affect a person's hearing, so use a normal tone of voice.
- Ask before giving help. When offering to assist someone with a visual impairment, allow the person to take your arm. It is helpful to give verbal instructions regarding stairs, changes in levels, and other barriers.
- Do not pet service dogs when they are working unless the owner tells you that the dog is at rest or play. When walking beside the owner, choose the side of the person away from the dog.

- If you believe a person with a visual impairment needs help navigating (e.g., walking down stairs), first, ask if you can be of any assistance. If the individual does ask for assistance, guide his/her hand to the railing of the staircase.

Guidelines for Conversing with People Who Have Hearing Impairments:

- Before addressing people with hearing impairments, you may gently wave your hand in their line of vision or lightly tap their shoulder.
- When establishing whether a person with a hearing impairment can read your lips, look directly at the person and speak clearly, keeping your hands away from your mouth. Don't over-exaggerate your speech and never yell; this makes lip reading more difficult. It isn't necessary to slow down your speech unless you're asked to do so.
- Allow a clear view of your face by placing yourself near a light source and by keeping food and gum away from your mouth when speaking.
- If a person doesn't understand you, rephrase the statement with different words that may be easier to understand when lip reading. Use gestures and body movements to help clarify your words.
- If there continues to be difficulty, try written communication, or arrange for a sign language interpreter for future communication.
- If an interpreter is present, speak directly to the person you are addressing, rather than to the interpreter.

Guidelines for Conversing with People Who Have Communication or Speech Impairments:

- Give your attention to the person who is speaking, even if an interpreter is present.
- Be patient; don't speak for the person. Let the person finish his/her own sentences.
- Be supportive and encouraging by maintaining eye contact and refraining from looking at your watch or tapping your foot.
- Ask questions that only require short answers.
- If you aren't sure you understood something, repeat what you did understand and wait for further explanation. Pretending to understand is not helpful.

Guidelines for Conversing with People Who Are Developmentally Disabled:

- Speak slowly and clearly. Use gestures and physical movements to assist in being understood.
- Keep a positive tone and positive facial gestures. Do not make movements that may be perceived as threatening.
- Treat people as they are. If they are adults, treat them as such. Don't expect that people with developmental disabilities are like children. It is helpful to ask yourself: "Am I asking a developmentally disabled person to do something that I would ask anyone his/her age to do?"
- Ask before assuming that someone needs or wants assistance.
- Use specific and clear language.
- If a response is delayed, wait; the delay may simply mean the person needs more time to formulate an answer.

Guidelines for Instructors: Students with Visual Impairments

- Read aloud any instructions or material written on the board or on overheads used in the lecture.
- Give directions to the restrooms, laboratory, or classroom clearly, stating the distance.
- Allow students who are visually impaired or blind to make audio recordings of the lecture. The student will notify you in advance of such requests. Tape recorders or other recording devices for student use are available through student services programs.
- Allow students who are visually impaired or blind to bring note takers or Braille equipment with them into the classroom. Again, you will be notified in advance.
- Work with students and your campus office for students with disabilities to get appropriate formats of course materials to students in advance of the class. Electronic versions of documents generally offer the most flexibility, but each student may have unique needs.

Moving Forward

Discussing Student Marginalization [35]

> *Find a way to relate the material to what the students already know, either by relating it to everyday experience or to material from a pre-requisite course.*

Discuss the classroom environment as part of the introduction to the course. Make sure that every student, regardless of gender, ethnicity or background, will be treated fairly throughout the semester. Every individual should have equal opportunities to contribute and to learn. Make students get into small groups or talk to other students near them, and ask them to think of a couple of reasons why some students may feel left out or silenced in the class. Then, write down the reasons they generate on the board and ask the whole class to brainstorm for solutions.

Introducing the Material[36]

Sometimes instructors jump right into the subject material and worry about procedural matters during another class period. Sometimes instructors manage to go over policies and procedures, and still have time left over to introduce the course material. In any case, getting students involved in the subject matter right away is a good idea, even if it is for a brief period of time. Pick an aspect of the course that you find most exciting. Your enthusiasm will become contagious. Furthermore, find a way to relate the material to what the students already know, either by relating it to everyday experience or to material from a prerequisite course. Try to get the students actively involved on the first day and to address students' concerns.

Use the first day to help your students understand how the class will serve their needs, show your commitment to help them, and create a comfortable, open, and inclusive classroom community conducive to inquiry and participation. It would also be helpful if you itemize your time with them. This would involve identifying for yourself how much time you will allot to various topics. You might devote 5 minutes to introducing the basic outline for the course, 15 minutes for students to interview each other, etc. (For information about procedures for the first day in a science lab, see "The First Day" in the Science Lab section later in Part Two.)

Summary of the First Day of Class

- ☑ Your conduct on the first day will set the tone for the rest of the course.
- ☑ Approach students with understanding and professionalism.
- ☑ Let your students get to know you. Share your enthusiasm for the subject you teach.
- ☑ Consider age differences in political views, activities, and sports and entertainment interests when interacting with students and giving assignments.
- ☑ If a student has a disability, use the guidelines listed above for courtesy and effective communication.

Lecturing[37]

The primary method used in STEM education is lecturing. Lecturing can be an effective strategy that has advantages and disadvantages for teaching and learning. The traditional idea of a lecture is a professor in front of a large class "speaking from the chalkboard," with perhaps the occasional question. However, even lectures of 400 students can still involve active learning — questioning, discussing, and participating. Some strategies can be done with groups of 80-100 students, but are impractical for 400 students, while others are best done with groups of 50 students or less.

The traditional idea of a "lecture" section accompanied by a lab or discussion section does not necessitate that lecturing occurs in and only in the lecture section. Deciding whether to use a lecture technique should be a choice based upon the particular situation, what content is to be presented, and what will most help students learn.

Strategies for Effective Learning[38]

Communicate effectively with all students

- Choose a simpler word when lecturing, while offering a more complex term in hand-outs.
- Learn and use students' names.
- Eliminate slang and informal expressions. For example, "That is not necessary" is easier to understand than "You don't have to do that."
- Limit the use of two and three-word verbs (run into, get across, etc.). For example, "I will organize that" is easier to understand than "I'll set it up."
- Use Latin-based root words in place of more casual choices. Latin-rooted words in English generally indicate a more formal or academic speaking style. The non-native speaker is more likely to have studied a more formalized, generic form of English in his or her home country or intensive ESL program.
- Refer students with difficulty in oral or written expression to tutorial or training programs for extra help.
- When using fictitious names, include ones such as Nguyen ("new-win") or Durai ("do-rye") in addition to the "traditional" Smith, Jones and Brown.

Don't just teach the material, teach how to learn

- Ask questions in class and wait to get answers (at least five seconds) — allow silence.

- Show students how to perform important course skills — model the process of analyzing a research report, rather than assuming that students know how to do this.
- Have extra sessions on note-taking and effective study practices.
- Encourage students to use campus tutorial, study skills, and writing services.
- Provide extra material or exercises for students who lack essential background knowledge or skills.
- Recognize that not all students seek advice and guidance when needed; be prepared to reach out to those who might not otherwise seek help.

Remember it's all about people

- Personalize the course for students.
- Find out about students' learning styles, interests, and backgrounds at the start of the course. (See "Getting to Know Your Students," earlier in this chapter, for specific suggestions.)
- In large classes, find ways for students to get to know one another, and encourage students to form study groups.
- Incorporate the contributions of foreign-born scholars in citations of scholarly accomplishments.
- Include real-life examples of documents prepared for and by internationally-based clients rather than focusing on just North American and western European samples.
- Use topics such as the impact of international trade on local economies to solicit and encourage the opinions and participation of students who have lived abroad.
- Encourage international students to undertake research projects which will provide experience relevant to their future environment, since many will return to their countries of origin after graduation.
- Pair undergraduate students with mature students already in the workforce so that shared experience contributes to realistic research and writing.

Advantages and Disadvantages of the Traditional Lecture Method[39]

Advantages

- Gives the instructor the chance to expose students to unpublished or not readily available material.
- Allows the instructor to precisely determine the aims, content, organization, pace and direction of a presentation. In contrast, more student-centered methods, e.g., discussions or laboratories, require the instructor to deal with unanticipated student ideas, questions and comments.
- Can be used to arouse interest in a subject.
- Can complement and clarify text material.
- Complements certain individual learning preferences. Some students depend upon the structure provided by highly teacher-centered methods.
- Facilitates large-class communication.

Disadvantages

- Places students in a passive rather than an active role, which hinders learning.
- Encourages one-way communication; therefore, the lecturer must make a conscious effort to become aware of student problems and student understanding of content without verbal feedback.
- Requires a considerable amount of unguided student time outside of the classroom to enable understanding and long-term retention of content. In contrast, interactive methods (discussion, problem-solving sessions) allow the instructor to influence students when they are actively working with the material.
- Requires the instructor to have or to learn effective writing and speaking skills.

Enhancing Learning in Large Classes[40]

Despite the limitations of traditional lectures, many institutions are forced to offer high-enrollment introductory science courses. Many professors who teach these courses feel that lecturing is their only option, and can only imagine what they could accomplish in smaller classes. However, there is a small but growing group of science faculty members who have developed ways to engage students in the process of thinking, questioning and problem solving despite their large class sizes.

When lecturing is the chosen or necessary teaching method, one way to keep students engaged is to pause periodically to assess student understanding or to initiate short student discussions.

Hints for More Effective Lecturing

When lecturing is the chosen or necessary teaching method, one way to keep students engaged is to pause periodically to assess student understanding or to initiate short student discussions. Calling on individual students to answer questions or offer comments can also hold student attention; however, some students prefer a feedback method with more anonymity. For example, if students have an opportunity to discuss a question in small groups, the group can offer an answer, which removes shy students from the spotlight. Another option is to have students write their answers on an index card and pass the card to the end of the row; the student seated there can select one answer to present, without disclosing whose it is.

Other literature on teaching and learning contains other examples of techniques to maintain students' attention in a lecture setting.

- ☑ Avoid direct repetition of material from the textbook, so that it remains a useful alternative resource.
- ☑ Use paradoxes, puzzles, and apparent contradictions to engage students.
- ☑ Begin each class with something familiar and important to students to pique their interest.
- ☑ Make connections to current events and everyday phenomena.
- ☑ Begin and end each class by summarizing the main points of the lecture.
- ☑ Adopt a reasonable and adjustable pace that balances content coverage and student understanding.
- ☑ Relate lecture materials to past or future presentations.
- ☑ Throughout the lecture, check on student understanding by:
  - Asking students to answer specific questions; present a problem or situation which requires use of lecture materials to find a solution.

- Asking for student questions and waiting at least five seconds for responses.
- Watching the class for nonverbal cues of confusion, such as loss of eye contact, talking, clock watching, etc.

☑ Consider using slides, videos, films, CD-ROMs, and computer simulations to enhance presentations, but remember that:

- Remember that students cannot take notes well in darkened rooms.
- Present text so that it is large enough to read from the back of the room.
- Allow students sufficient time to summarize their observations and to draw and note conclusions.

Transitioning Students to Become Active Participants

There are several ways to help students make the transition from passive listeners to active participants in their own learning (Orzechowski, 1995).

☑ Start off slowly; students may not have much experience with active learning.

☑ Introduce change at the beginning of a course, rather than midway through it.

☑ Avoid giving students the impression that you are "experimenting" with them.

☑ Don't give up lectures completely.

☑ Anticipate students' anxiety, and be prepared to provide support and encouragement as they adapt to your expectations.

☑ Discuss your approach with colleagues, especially if you are teaching a well-established course in a pre-professional curriculum.

Case 1: Biochemistry, Genetics, and Molecular Biology at Stanford University

Professor: Sharon Long
Enrollment: 400 students

One important tool I use to engage students is to create opportunities for thought and for active pursuit of an unknown during the class session. If I give a lecture for which I provide notes — a common practice — I always leave blanks in critical parts of the notes. On the board or transparency, I indicate the unknown. I pause while I talk about it, drawing the students' attention to the hole in the notes. If possible, I ask for suggested answers or for a vote among the possibilities. By arranging the pause in your lecture, you can give the students the chance to answer the question themselves and to work on the questions independently. And only by attending class can a student gain all the information — which encourages class attendance.

In teaching formal genetics, I draw out a genetic cross first in general form (in this example, a Drosophila eye color inheritance test): w^+y x w w

Then I put into the lecture notes a completely blank Punnett square to show the structure of the approach — but not to provide the answer.

Female gametes:

Male gametes:

The students encounter this as an unknown, because I address the contents of each line, and each box, as a question. ("Everybody, consult with your neighbor for a minute — now, second row, anybody tell me, what should be in these two blanks at the top? What would be the genotype and phenotype for the bottom right box?")

Chalkboard Technique[41]

Your students need to see and read what you have written.

Write legibly and in large enough print so what you write can be seen in the back row. (And if you're uncertain what that means, take a stroll to the back of the room and look at your work the way your students see it). Don't write all the way down to the bottom of the board. Keep desks or tables in front of the board clear of objects like briefcases and lecterns.

Students need adequate time to copy what you write.

Don't erase a filled board before you need it again. If you're right-handed, consider starting on the right-hand board and working your way to left panels. This way you won't obstruct the view of the already-filled boards as you continue. Despite instructions to the contrary, some students will write down everything you put on the board. If you want students to analyze an idea, they won't begin to 'think' until they have finished copying. So when you want to make a major point, stop your board writing. Let students catch up. Then, begin discussing your point.

Avoid working with an eraser in hand to simplify or to correct board steps.

It's easily done at the chalkboard, but less easily accomplished in a notebook, and is guaranteed to irritate students taking notes. Rather than revising by erasing, draw a line through the offending terms and write new entries above or below.

Writing Assignments in the Lecture[42]

Here are a variety of small writing assignments for the STEM classroom:

- ☑ Have a supply of 3x5 index cards in the back of the lecture hall for students to use to write questions about the lecture. Answer the best or most frequently asked questions at the start of the next class.
- ☑ Ask an occasional quiz question in class: "What's so fundamental about the fundamental theorem of calculus?" "Describe one application of today's topic."
- ☑ At the end of the solution of an exercise, ask the students to describe the real-world implications of the answer they just got.
- ☑ Have the students write out a description of the topics covered since the last exam, as well as why those topics might be important or useful.

None of the above assignments takes a long time to construct, nor is it difficult to grade. Yet each enhances the students' awareness of the usability of the classroom material. Further, each asks the students to think a bit more holistically and carefully about the deeper meanings of the materials they are studying. Of course, the above are only a small sampling of the possibilities of writing assignments.

Engaging Women in Math and Science Courses[43]

> *Studies monitoring female (and minority) students' progress through math and science departments show that these students frequently abandon their intended majors because they do not receive enough encouragement from their peers and professors.*

The lower numbers of women who take science courses during college reflect attitudes, developed at an early age in U.S. students, toward the "masculinity" of these fields. Studies show that peers, teachers, counselors and family members frequently dissuade both female and minority students from taking upper-level mathematics and science courses (Clewell, Anderson & Thorpe, 1992). By the time female students enroll in a required math or science course, they may very well bring with them a considerable amount of anxiety, and may fear that this course will be particularly difficult for them because they are female.

This anxiety may heighten when a woman looks around her and sees that a majority of the other students are male and that a male teacher is presiding over the class. The instructor must not only recognize the female students with math or science anxiety, but also notice potential female science or math majors who are not receiving enough support for their interests. Studies monitoring female (and minority) students' progress through math and science departments show that these students frequently abandon their intended majors because they do not receive enough encouragement from their peers and professors. They may also feel inhibited in a predominantly male/majority atmosphere. One woman planning to major in a science reported that, in one class she took, the continual sexual joking between the male students created a male community that made women feel like outsiders. The professor did not stop the students' behavior, and even participated in the joking on several occasions. The student commented that it upset her to see this kind of behavior go uncensored in her classes because, although she herself felt well-informed enough to understand what was happening and could confront the professor, many women do not know how to confront sexist behavior:

> "There are a lot of women who don't have the background in talking about this kind of stuff, and aren't going to know why they don't like it. They're just going to change their major[s]."

As a math or science teacher, you can have a tremendous influence on women in your class. First, establish a professional atmosphere that is comfortable for men and women alike. Second, make female students aware that they are capable of learning the material, and encourage those who perform well to take additional courses in the department or to pursue advanced studies in the field. Students who do well in these fields often credit a teacher as having been an important influence (Clewell, Anderson & Thorpe, 1992).

When it is relevant, make reference to women currently conducting important research in your field. When talking about hypothetical scientists or mathematicians to illustrate a point, make sure you occasionally assume the scientist or mathematician is a woman. By doing this, you send out a message to students that your field is open to women as well as men.

In addition, rather than teaching only mathematical formulas, make an effort to show how they can be used outside the classroom. By showing the relevance of these concepts to solving "real-world" problems, you are more likely to make both male and female students aware of the importance of your discipline and to awaken their curiosity to discover more about it. For more detailed discussion of strategies for including women in your science class, consult Sue V. Rosser's *Female-Friendly Science* (1990), especially Chapter 5, "Toward Inclusionary Methods."

Formulating Effective Questions[44]

Different types of questions will elicit different responses from students. Two pairs of question types may be particularly helpful in planning questioning strategies.

1. *Initiating vs. Probing Questions*

An **initiating question** begins consideration of a particular topic. Initiating questions can be planned in advance to make them suitably interesting. Initiating questions can be arranged in sequence from simple to complex to fully develop the various aspects of a concept. Frequently, you will find it desirable to follow the initiating question with one or more **probing questions**. A probing question is asked of the responding student to bring out more of what he/she knows about the subject. Probing questions are not easily planned; the nature of the probing question depends upon the student's initial response.

2. *Convergent vs. Divergent Questions*

Convergent questions require students to solve problems which have a single correct answer**. Divergent questions** require examination of problems for which many answers are plausible. For example, a standard organic chemistry text may provide students with sufficient reactions such that one general synthesis may be approached through five routes. An instructor may want to get students to first come up with several of these routes (a divergent task), and then to evaluate them so as to select one best available route (a convergent task).

Formulating Questions

The way in which you state your question will often determine its effectiveness. Here are a few points to think about:

☑ *Plan some questions as you prepare.*
While making your lesson plan, consider your instructional goals and emphasize questions that reinforce them. The questions you ask will help students see what topics you consider important.

☑ *Use vocabulary familiar to students.*
Students cannot respond well to a question that contains unfamiliar terms. If students seem to have a hard time answering after waiting five to ten seconds, rephrase the question or try explaining confusing vocabulary. Be sure to use vocabulary that does not have a specific cultural bias.

☑ *Ask questions from all intellectual levels.*
Create questions which take all levels of comprehension into consideration (see "Defining Instructional Objectives"). Mixing more difficult questions that require synthesis and evaluation in with simple questions that require memorization keeps students actively switching gears and gives you a sense of how students' learning is progressing.

☑ *Avoid ambiguous questions.*
When you formulate an oral question in class, think of the corresponding direction you would give for a written exam question. This will help to avoid ambiguous questions.

☑ *Avoid "yes" and "no" questions*.
For example, the question "Is carbon monoxide considered a pollutant?" is almost certain to be followed by "Why is carbon monoxide considered a pollutant?" You might as well begin with the second question.

☑ *Avoid double-barreled questions*.
Questions that pose two problems simultaneously are confusing and are to be avoided. For example, the question "What is the difference between fission and fusion, and how is electrical power generated from these reactions?" is actually a three-in-one question.

Questioning and Responding Techniques

The manner in which you ask questions and treat responses is as important as anything else involved in questioning. Thus far we have dealt with the levels of questions, the strategy of selecting questions, and the phrasing of questions. Even though these aspects of questioning are important, the efforts you expend on these tasks is lost without follow-through in managing the questions.

- *Wait*.
  After you ask a question, other than a memory or recall question, wait about three seconds before selecting a respondent. Do this even if someone volunteers immediately. After a student responds, wait about five seconds before you respond to the answer. By waiting after your question, you give everyone in the class an opportunity to think about a response. If you pick a respondent immediately, other students are under no pressure to think about a response. They may listen to the respondent, or they may pay little attention. By waiting after a response, you give the respondent an opportunity to expand upon his/her answer. Frequently, the student will initiate an extended response, and thus you won't need to use a probing question to elicit the extended response.

- *Distribute questions*.
  Distribute questions among students so that many can participate. Be sure not to call on students from only one particular group. You should choose from among volunteers, but you should also feel free to call upon students who are not volunteering.

- *Reinforce responses*.
  You may reinforce responses with verbal praise ("Good!" "Excellent!" etc.) and with non-verbal encouragement (smile, nod). You may also reinforce a student's response by repeating the response. Never ridicule an answer. You may be tempted to do this when a student makes a response indicating that she or he has been inattentive or has not prepared. The problem with such ridicule is that the

act of responding is punished along with the response. While the student subjected to ridicule is less likely to respond incorrectly in the future, the student's peers feel that their safety in responding to questions is threatened, and the overall response frequency is lowered.

- *Let students correct each other*.
  Use your students to reinforce answers and to help you eliminate erroneous responses. For example, ask the class to comment on respondents' answers both when they are correct and when they are incorrect. This is a good way to allow students' peers to deal with incorrect responses.

- *Encourage student debate*.
  When you are using divergent questions, it is particularly helpful to get students debating with one another. For example, when two students have each devised synthetic routes to a compound, debate about which route is the preferred route. This will be a valuable learning experience for both the students and the class.

- *Have students formulate questions prior to class*.
  Any time you assign reading, math problems, experiments, case studies, journal writing, etc., ask your students to prepare three questions they had while they were completing the assignment. Also, you might ask them to write three questions they might be expected to answer on a quiz covering the material they encountered. Begin class by having your students share their questions in small groups or as a whole. Their questions will not only stimulate discussion but also will allow you to determine confusing aspects of the material. In addition, being able to anticipate questions a teacher will ask on exams is an important study skill for students to develop.

Summary of Lecturing

- ☑ Use concrete examples to relate the material to students.
- ☑ Use a variety of presentation methods such as multimedia, guest lectures, etc.
- ☑ If students have accessibility needs, make necessary accommodations; use a lapel mic, give handouts of lecture notes, etc.
- ☑ Don't just talk for 50 minutes; give quick writing assignments, break individuals into groups, and ask engaging questions.
- ☑ Directly reference the work of men and women of many different ethnicities.
- ☑ Think about what questions you are going to ask before you come to class.
- ☑ When asking questions, give students a few seconds to think before calling on someone.
- ☑ Be sure to call on all students equally.
- ☑ Make the effort to get to know your students as individuals as much as possible.

Discussion[45]

Class discussion or small group discussions can be used to accomplish a variety of learning goals. Discussion is a primary form of active learning, and will often help students understand and remember material better than a simple lecture would. Many courses have a "discussion section" separate from a "lecture section" or "lab section." Some class sizes are small enough for the instructor to conduct class periods as group discussions. In larger classes, it might take time to break the class into small groups for discussion. Although parts of this section speak directly to you as if you were leading a semester long discussion section, the information throughout the section is valuable for any type of class discussion. The collaborative exploration of concepts and ideas by a diverse group of students in a safe and fair environment can lead to tremendous student learning.

Brief Overview[46]

The General Precepts

These generalizations will provide some useful perspective before we discuss the nuts and bolts of managing a discussion.

1. Be Prepared.
You obviously won't enter a discussion session with a word-by-word script, but you should know what types of problems and/or topics you intend to cover and how to go about these tasks. Nothing undermines class morale more quickly or completely than an unprepared instructor.

Think of a science-related anecdote or a short comment on material presented in the previous lecture to use as a possible opening ice-breaker for the session. Such planning is infinitely better than asking "O.K., gang, any questions?" as a means of stimulating interest and participation.

Encourage students to come prepared to discuss and to take full advantage of the time. Be ready to ask them questions if they don't question you. Arm yourself with plenty of back-up problems or exercises supporting current topics, to help students who are unable to identify troublesome homework items or points to discuss. Don't excuse students early because they don't have any questions.

2. Don't be afraid to show warmth and concern.
Treat students with respect and consideration; try to be sympathetic to difficulties they may encounter.

You may find certain students' lack of ability and apparent unwillingness to learn annoying, frustrating and, at times, exasperating. Displays of disgust, contempt or ridicule, however, all aggravate the situation and diminish students' respect for you.

Avoid conveying a sense of self-importance and superiority by showing how simple and self-evident your discipline is for you. Such an attitude turns students off quickly.

Identify with your students as much as possible by recalling reactions you had the first time you encountered such material (which may not have been that long ago). This may help you to avoid the trap of expecting excessive student respect simply because you know more than they do.

3. Be yourself.
Realize that concern and compassion are not synonymous with a lack of control, nor is informality necessarily associated with a lack of preparation or organization.

If you are effective in an informal atmosphere without losing class control or student respect, then, by all means, do so. If, on the other hand, you're more comfortable and effective in a less casual, more structured environment, don't try to fake the "good buddy" routine. You're not at your best when you're ill at ease from trying to assume a character that isn't you.

Identify with your students as much as possible by recalling reactions you had the first time you encountered such material.

A suggestion: previous generations of faculty have found that starting off with a more formal, no-nonsense approach and later easing up with discretion is easier to accomplish and better received by students than trying to "tighten up" after a class has seen fit to take advantage of a casual, easy-going approach.

The "Nuts and Bolts" of Discussion[47]

Ground Rules for Discussions

Establishing ground rules can be a way to have students take responsibility for creating a classroom environment conducive to learning. From the outset, by gaining class consensus on ground rules, teachers can enlist student support in their enforcement.

1. Share experience
Rather than generalizing about whole groups of people, ask students to use "I" statements and speak from their own experience. This also invites diverse perspectives from students who often find themselves on the fringe of classroom life, such as gay, lesbian and bisexual students, older students, women and students of color.

2. Participation
Ask students who know they tend to monopolize discussions or interrupt others to self-monitor and make room for quieter students. At the same time, encourage students who tend to be quieter to enhance everyone's learning by sharing their unique perspectives and experiences.

3. Confidentiality
Encourage students to take concepts and ideas from class and discuss them freely. However, personal stories raised by individuals should be kept confidential.

4. Respectful Listening
Encourage students with differing points of view to raise questions by listening first. Add that if someone raises a point a student strongly disagrees with or finds offensive, it is important for the student to inform others. It is also important to remember that the human being stating the question or comment deserves respect, even when one disagrees with what they are saying.

5. No Zaps
Tied to the notion of respect is the ground rule of no put-downs in class, not even the humorous variety called "zaps." To "zap" one person often discourages open and honest exchange of ideas among the group.

6. Be Clear and Concise
Encourage students to ask for clarification when they don't understand a point someone has made. Everyone should be efficient in their discourse, making points and then yielding to others.

7. Challenge and Be Challenged
Ask that if students challenge others' ideas, they do so with factual evidence and appropriate logic. If others challenge their ideas, they should be open to the possibility of changing their minds if errors in their logic or use of facts are demonstrated.

Facilitating Discussion of Sensitive Issues[48]

In many disciplines, the discussion of race, culture, gender, and/or sexual orientation in relation to social issues is an appropriate part of the curriculum. However, faculty and students are often uncomfortable addressing such issues, fearing embarrassment or conflict. Techniques that may help overcome this discomfort include:

- Start with less controversial topics before tackling more sensitive ones.
- Set ground rules for class discussion, based on an agreement to honor others' differences and experiences.
- Acknowledge that a certain amount of conflict may be necessary for the learning process.
- Use role-playing or debates to help students see how others might perceive issues differently.
- Have students respond to controversial statements posed by the instructor.
- Ask students to complete anonymous in-class surveys on controversies; use data from the surveys as the basis for discussion.

- De-personalize a student's biased or inflammatory remark before continuing (e.g., "That's something that a lot of people believe… Why might someone think that way?").
- Identify the issue that is the source of controversy and make it an analytic question; ask for evidence.
- Avoid "tokenism." Don't assume, for example, that a student who uses a wheelchair can represent the views of all Americans with disabilities.

Encouraging Student Contributions[49]

There are several strategies that facilitate student contributions to discussion. First, it is important to think about using classroom space wisely. For example, having the students sit in a circle may differentiate this setting from the lecture setting, as well as encourage the students to talk to each other and not just to you. Second, learning students' names quickly helps establish rapport. The easiest way to learn students' names is to take digital pictures and attach names to the faces. Third, set some ground rules for discussion, preferably with the help of students. Finally, it is important to strike a balance between encouraging students to contribute and providing corrective feedback.

Suggestions for rewarding student contributions:

- Talk directly to the student who contributes.
- Put student comments on the chalkboard/whiteboard.
- Make eye contact and use the student's name.
- Listen carefully and ask follow up questions, then paraphrase the comments.
- Ask the student to restate complex or inaudible comments for the whole class, or do so yourself when necessary.
- Point out specifically what you thought was valuable in the contribution.
- If you see potential in a comment, ask the student for elaboration, application or continuation of the point.
- Incorporate student points in later material.
- Invite other students to add their reactions to build further on the original point. Be sure to include every student in the discussion.
- Comment on the thinking process the student has used, as well as the point the student made.
- If a comment is unclear or confused, help the student express his or her original intent.

- Use non-verbal messages to reward students for participating, regardless of the substance of their comments.

Suggestions for providing corrective feedback without discouraging students:

- Be clear about the difference between what is incorrect and what you disagree with.
- Before you disagree with or correct a student, restate the point to test your understanding.
- Admit your ignorance. If you don't know something, say so. Refer the student to other sources or offer to get the information.
- When you criticize a comment, ask for reactions. This keeps a dialogue going and makes students less likely to withdraw.
- Be specific in both positive and negative comments.
- When making criticisms, explain your reasons.
- Encourage students to respond to each other's ideas.
- Respond to discriminatory comments immediately, explaining why some individuals might find them offensive.
- Be sensitive to student pride and fears. In putting forward an idea, a student is also putting his or her self-esteem on the line.
- Avoid any tone of condescension. A student who is working on an idea, however elementary, deserves respect.
- Recognize that all students have to worry about grades.
- Leave your ego outside the classroom. Do not try to look good at the expense of a student.

Alternative Instructional Methods[50]

Seminars and tutorial sections vary enormously in their types and purposes. In addition to group discussion, any of the following methods may be used, depending on the purpose of the instructor:

- Buzz groups
- Panels
- Symposia
- Debates
- Experience discussions

- Brainstorming sessions
- Case studies
- Jigsaws

1. Buzz Groups

Description All group members participate in small subgroups, and then take part in a discussion with the entire group.

When Used When participation from every group member is desired; in conjunction with other group methods.

Procedure Prepare one to two questions on the topic to give each group. Divide the members into small subgroups of 2 to 4 individuals. Choose a leader in each subgroup to record and report pertinent ideas to the whole group.

Limitations Thought must be given to the purpose and organization of the groups (e.g., including a variety of ability levels). Success is dependent upon the kinds of questions selected and the suitability of those questions.

2. Panels

Description A selected group of persons with a leader converse in front of an audience that joins in later.

When Used As a technique to stimulate interest and thinking; to provoke better discussion.

Procedure The leader plans the conversation with the four to six panel members, each of whom is given a specific topic to study. The panel discusses the topic informally without set speeches. The leader opens the discussion to the group and summarizes what others have said.

Limitations This process can get off track. The personalities of the speakers can overshadow the content of the discussion. A vocal speaker can monopolize the program if the leader is ineffective.

3. Symposia

Description A topic is broken into various parts: each part is presented by an expert or well-informed person in a brief, concise speech.

When Used When specific information is desired.

Procedure The facilitator meets with three or four group members and plans an outline. Participants are introduced and give reports. The group questions the speakers. The facilitator summarizes what has been said.

Limitations This process can also get off track. The personalities of the speakers can overshadow the content. A vocal speaker can monopolize the conversation. Speaking times can vary; it is important to adhere to a schedule.

4. Debates

Description A controversial issue is discussed, using a pro and con comparison. The objective of the debaters is to convince the audience rather than to display skill in attacking the opponent.

When Used If a controversy exists on which there are fairly definite opinions on both sides, such debates can bring these differences out in the open in a friendly manner.

Procedure Divide the group into sides. Each speaker should be limited to a predetermined time, followed by time for rebuttal if desired.

Limitations Members may have difficulty defending a view which they do not hold themselves. The emphasis on taking sides can be divisive and may inhibit learning for some students.

5. Experience Discussions

Description A small- or large-group discussion takes place following a report on the main point of a book, article, or life experience.

When Used To present a new point of view or an issue; to stimulate thought and discussion.

Procedure Plan with participants how the review is to be presented. Then have an open discussion on pertinent issues and points of view.

Limitations Students may need assistance in preparing a presentation that will lead effectively to a class discussion.

6. Brainstorming Sessions

Description This is a creative thinking technique in which group members think about a problem or topic and then share all the ideas they can come up with.

When Used To get new ideas and foster individual students' ability to think of ideas.

Procedure The facilitator and members of the planning group select suitable problems or questions related to the topic selected by the entire group. The leader explains to the group the meaning of brainstorming and the following rules:

- criticism is applied later
- many ideas are wanted
- the more ideas, the better chance there is of developing good ones
- the wilder the idea, the better, since it's easier to tame them down than to pump them up
- "hitching is legitimate" – if you can improve on someone's idea, so much the better

- a recorder should list the ideas

Limitations This method is not practical with more than 20 people. Brainstorming becomes disorganized without careful planning of the material to be covered and skillful direction from the discussion leader.

7. Case Studies

Description An actual account of a particular incident and/or problem is presented to the class – including how the matter was resolved.

When Used When a specific example is the best means of illustrating a topic. This method is often used to supplement traditional lectures. It can also be used to synthesize ideas and to apply theory to practical problems.

Procedure The facilitator documents a case study, altering actual names and places if required. The case study is presented to the class, and is generally followed by discussion.

Limitations Case studies require additional work by the facilitator to ensure that they are straightforward and good examples of the issue being represented.

8. Jigsaws

Description All group members participate as both experts and learners. This is often followed by a problem-solving situation where all the knowledge must be used for the group to succeed.

When Used When participation by every group member is desired and the subject, topic or skill is easily broken down into manageable chunks.

Procedure Students work in small groups (expert groups) to master the material. The facilitator rotates among the groups to answer questions and make sure the material is being mastered and understood. Students return to their home groups, which include one member from each expert group. They teach each other their areas of responsibility and then use the new knowledge to solve a problem, write a group essay or exam, etc.

Limitations Thought must be given to the purpose and organization of groups (e.g., including students with a variety of abilities). Success is dependent on the kind of material chosen and the final problem to be solved.

Reevaluate your pedagogical methods for teaching in a diverse setting.

Observers note that in discussion sections, instructors tend to favor students who question assumptions, challenge points of view, speak out, and participate actively (Collett, 1990; Institute for the Study of Social Change, 1991). Recognize, however, that some of your students were brought up to believe that challenging people who are in positions of authority is disrespectful or rude. Some students may be reluctant to ask questions or to participate out of fear of reinforcing stereotypes about their ignorance. The challenge for teaching a diverse student body is to be able to engage both verbally assertive students and those with other styles and expressions of learning (Institute for the Study of Social Change, 1991).

Speak up promptly if a student makes a distasteful remark, even if the student is joking.

Don’t let disparaging comments go unnoticed. Explain why a comment is offensive or insensitive. Let your students know that racist remarks, sexist comments, and other types of discriminatory statements are unacceptable in class. For example, “What you said made me feel uncomfortable. Although you may not have meant this, it could be interpreted as saying...”

Avoid singling out students as spokespersons.

It is unfair to ask a student to speak for his or her entire race, culture, or nationality. To do so not only ignores the wide differences in viewpoints among members of any group, but also reinforces the mistaken notion that every member of a minority group is an ad hoc authority on his or her group (Pemberton, 1988). For example, avoid, after lecturing on population genetics and theories of racial intelligence, singling out an African-American student in the class to ask him about his reactions to the theories. Furthermore, do not assume all students are familiar with their ancestors’ language, traditions, culture, or history. For example, avoid asking an American-born student of Chinese descent, “What idiom do you use in Chinese?” (Flick, n.d.; Pemberton, 1988).

Potential Problems in Discussions [51]

Maintaining discussions often means dealing as smoothly as possible with the problems that arise. Here are some common problems with suggestions for how to deal with them.

The student who talks too much

A way to approach the avid talker and pull in non-participants is to avoid looking in the direction of the persisting student or to structure the discussion in a way that precludes that person’s participation, e.g., saying “Let’s hear from someone who has not yet contributed.” Instructors might also ask one or more members of the class to act as observers for a few class periods, reporting back their observations to the class. Perhaps assigning the avid talker to the observer role would help the student develop sensitivity. Another technique is to talk to the student individually outside of class.

The student who will not talk

Instructors need to set clear expectations for participation. It is also important to reinforce participation. A way to approach non-participants is to provide opportunities for small group discussions. Smaller groups may help put some students at ease. A second strategy is to ask opinion questions occasionally (e.g., "How do you feel about this?"). This may encourage participation by reducing students' fear of answering incorrectly. Another strategy is to have students write out their answers to a question. Having the words written out may make it easier for a shy or fearful person to speak up.

The discussion that turns into an argument

In good discussions, conflicts will often arise. If such conflicts are left ambiguous, they may cause continuing trouble. Here are some ways to resolve them:

- If the solution depends on certain facts, the instructor can ask students to refer to the text or another authority.
- If there is an experimentally verified answer, the instructor can use the opportunity to review the method by which the answer could be determined.
- If the question is one of values, the instructor may use the occasion to help students become aware of the values involved.
- The instructor can list both sides of the argument on the board.
- The instructor can take a strong position as moderator, preventing students from interrupting each other or speaking simultaneously. She or he can lay ground rules for discussion, such as asking students to focus conflict on ideas rather than people and to resist being judgmental.

Unclear or hesitant comments

The instructor can encourage students making unclear contributions to give examples and factual evidence of their points. The instructor can also restate points for verification or rejection by the students, or give enthusiastic nonverbal cues and patience.

The discussion that goes off track

Some instructors keep discussions on track by listing the questions or issues they want to cover on the board or summarizing the discussion on the board as it proceeds. Stopping and asking a student to summarize where the discussion is at the point it appears to go off track may also help.

The student who attacks the instructor

When students argue for the sake of argument, instructors will usually lose if they take the bait. This situation often occurs when instructors are going over exams or assignments. Students who attack usually want attention, so simply giving them some recognition while firmly moving on often takes care of the problem. If students are simply trying to embarrass the instructor, they may seek to make him or her defensive with such comments as, “How do you really know that…?” or “You’re not really saying that…?” Such questions can be handled by playing boomerang. The instructor might say, “What I’m saying is…, but now I'd like you to share your perspective.” Turning the question back to the questioner forces him or her to take responsibility for his or her opinion. Other ways to handle these situations include:

- *Confrontation*
  Instructors can confront the questioner with their reactions to his or her behavior. “I’m uncomfortable with the imprecision of your questions. What I really hear you saying is...”

- *Active listening*
  Instructors can paraphrase the message they heard and check out the accuracy of their assumptions before responding.

- *Locating*
  Instructors can ask the questioner to explain the context behind the question.

- *Reframing*
  The focus can be on clarifying the assumptions behind the person’s argument and then inviting her or him to see alternative possibilities.

- *Deferring*
  Often, the best strategy is to invite students to come up after class and arrange for a time to talk about the disagreement further, and then move the discussion on to another topic.

Summary of Discussion

- ☑ Act as a facilitator during discussion.
- ☑ When discussing controversial issues, use the strategic methods described above to depersonalize topics and make students more comfortable.
- ☑ Monitor your own behavior to make sure that all students are treated fairly.
- ☑ Set appropriate ground rules for discussion.
- ☑ Reward constructive student contributions; address behavior problems promptly and diplomatically.
- ☑ Experiment with alternative instructional methods to increase student participation and learning.

Expanding Teaching Strategies[52]

Using practical examples in the classroom can link abstract ideas to real world situations and help engage students from many perspectives. Teaching strategies such as case studies and brainstorming are particularly useful.

Practical Examples

Connecting Theory with Applications

Students have expressed concern regarding the need for more industrial and practical examples to reinforce theory in the classroom. The use of practical examples can help you connect theory with practical applications for more effective teaching and learning. The introduction of practical examples does not imply an elimination of theory, but rather an enhancement of the theory taught in the classroom. It is important to simultaneously develop a theoretical and a practical base for knowledge, since neither is useful without the other. The use of practical examples in the classroom is targeted at the following two main goals:

The use of practical examples can help you connect theory with practical applications for more effective teaching and learning.

1. Help to illustrate and explain new material, making the theoretical basis of the material more accessible to the students. Practical examples help students understand the new concepts being introduced.
2. Teach students how to apply their knowledge of course material to new situations that are not directly covered in class. The goal here is to show the students not only that what they are learning has practical applications but, more importantly, how to apply their understanding of the basic principles to real problems.

Scope

Practical examples can be included at all levels of the curriculum. When determining examples to be used for instruction, make the examples as clear and straightforward as possible. The key is to make the examples as simple as possible, and to make sure that they demonstrate the desired theoretical principle. Whenever possible, the examples should be designed so that the students' physical senses are brought into play. Examples that the students are likely to enjoy include those that require them to use their senses of sight, feeling, hearing or smell. Remember the following guidelines when implementing practical examples:

- Understand the example given and be able to explain it. If you cannot provide a clear explanation for the example, the example will confuse the students more than it will help them.

- Before giving a demonstration or take-home assignment, carry out the assignment yourself. This will ensure that you know exactly what the students will "see." It will also help you to anticipate questions. Giving an assignment or demonstration that doesn't work is frustrating to the students and is bad for your credibility.
- Choose examples that are relevant to the students. Examples that the students can observe first-hand – as opposed to those in a film, online or on TV – are better. Try to find examples that the students can observe on campus or at home. Pull examples from current events – like, for instance, explaining the cause for a design failure of a collapsed bridge recently in the news. Explain the basic principles behind a new or commonly used product, like the fluid mechanics aspects of a Bernoulli disk drive in a computer.
- Use examples that are not very well known to your students. Often, such examples will pique their interest more because of their novelty. If you do choose a well-known case, be careful; students may have preexisting assumptions about the material, which may or may not be grounded in fact.

Categories and Types of Practical Examples

Practical examples can be grouped into three broad categories:

A. Those that help in the explanation of theory and new concepts,
B. Those that illustrate the application of basic principles, and
C. Those that can both explain theory and new concepts and illustrate their application.

Practical examples can also be broken down into different types based on the format in which they are used.

Explanation of Practical Example Types

Analogy (A)
The analogy is a very helpful tool for explaining new concepts. Here, the instructor links the new concept to an idea which the students can easily picture in their minds. An example of an analogy would be to explain the concept of the conservation of energy in terms of money in a bank. One can imagine the money in a checking account as being analogous to kinetic energy. Similarly, money in the savings and money market accounts can be thought of as being analogous to pressure and potential energies, respectively. Just as money can be transferred between the three different accounts, so energy can be transferred between the three different forms. The concept of frictional energy losses can now be easily related to the debiting of money from the accounts (say, for paying the rent).

Sensing (B)
Sensing examples are designed so that students can "feel" the science behind the phenomena. The goal here is to have the students carry out experiments that allow them to sense the different parameters that enter into the theory. An excellent example of this would be to study the relationship between speed and torque for a gear system using a ten-speed bicycle. The students' assignment would be to flip a ten-speed bicycle upside down, switch through all the gear combinations while pedaling it by hand, and physically sense how the speed and torque for a particular gear setting are related. Clearly, the emphasis in this technique is not to teach or explain a new concept but to give a known concept more meaning by having the students sense it.

Secondary Effects (B)
Secondary effects demonstrate the fact that sometimes the explanation of an engineering phenomenon is not obvious. The purpose here is to get the students to really consider all the possible explanations besides the most obvious one. A classic example of this would be observation of the direction of movement of a helium balloon tied to the floor of a car when the car accelerates. Typically one would expect the balloon to move backwards when the car accelerates, due to the inertia of the balloon. This would be the case if a steel ball were to be suspended from the ceiling of a car. In reality, the students will notice that the balloon moves forward as the car accelerates. An investigation of the forces acting on the balloon can be done either as a homework assignment or as a class discussion. By doing so, the students should eventually come to realize that the balloon is pushed forward by the buoyancy force acting on it. As the car accelerates, the air in the back of the car is compressed slightly, resulting in a density gradient from the front to the rear of the car. The helium in the balloon is lighter than air and therefore experiences a buoyancy force in the horizontal direction.

Observations (C)
Observations that the student can make outside of class can help demonstrate basic principles currently being studied in class. The example can be carried out as a take-home assignment where the students are required to go and observe a phenomenon that they can readily see, feel, hear and/or smell, and to summarize their observations later. The students bring their observations to class and the instructor leads a discussion of what the students observed and what those observations mean. This type of exercise not only helps with the understanding of a new concept or basic principle, but teaches the students how to observe a phenomenon before trying to analyze it.

Demonstrations (Experimental or Mathematical) (C)
The demonstration example can be done either as an experimental exercise carried out in class with small models, or as a mathematical exercise carried out on the chalkboard or computer to explain a physical phenomenon. This can be particularly instructive when the students are aware of the phenomena but are not able to explain the science behind it.

Experimental (C)
An experimental demonstration requires physical equipment. While finding the right equipment may not always be possible, some examples require materials as simple as a paper clip or piece of paper. For instance, the factors affecting the aerodynamic drag and lift forces on an object can be demonstrated with a simple piece of writing paper. Hold a flat sheet of paper parallel to the floor and drop it, observing its rate of descent. Then take the same sheet of paper, crumple it up, drop it and observe its rate of descent. In both cases you have the same material, the same mass, and the same gravitational force acting on the system. Therefore, these parameters can be eliminated from consideration. By further eliminating other parameters, the students can be led to understand that the important parameter is the aerodynamic drag acting on the two different objects. Similarly, important governing parameters in other systems could be deduced. For instance, tests could be run with the same object shapes but with different projected areas. By observing how the time of fall depends on the various parameters, the students could arrive at the main governing parameters.

Mathematical (C)
The purpose of a mathematical demonstration would be to explain, using the theory developed in class, the science behind some phenomena that the students have seen or heard of. This can be particularly enlightening if the phenomenon is such that everyone knows about it, but few realize what really is happening. For instance, the term "valve float" in an internal combustion engine can be explained by modeling the valve as a train of solid links and springs, and then writing the equations of motion for the valve.

Show and Tell

Reversing Student Roles

> *If one can explain a concept to someone else, then [one] truly understands the concept.*

The "Show and Tell" technique is another form of the "Practical Examples" technique. However, in this technique the role of the student is reversed to that of a teacher, thereby changing the student's perspective of the problem. The basic premise of the "Show and Tell" technique is that if one can explain a concept to someone else, then one truly understands the concept.

Scope

A typical "Show and Tell" project would require a student or a group of students to explain a given theory or phenomenon to the rest of the class and to demonstrate a physical example that helps visualize the phenomenon. Almost any example that you can convincingly demonstrate in a classroom would be appropriate for a "Show and Tell" project. However, it should be remembered that, as with the case of the "Practical Examples" technique, the concept to be explained by the students should be relatively simple and straightforward. The purpose of this exercise is to challenge the students to come up with a creative solution to the problem at hand without overwhelming them. To avoid embarrassing situations and to ensure that the demonstrations are useful to the entire class, it is also important for you to know beforehand what the students plan to present.

Case Studies

Bringing "Real-Life" Scenarios into the Classroom

A case study is an account of an actual activity, event, or problem containing some of the background and complexities actually encountered by a practicing person in the field. Since cases are accounts of "real-life" activity, they help the students to better relate theory to the "real world." Cases often involve concepts from other disciplines like marketing and management, concepts that a professional needs to know anyway. In addition, the case method promotes discussion in class and feedback from the students.

A case study is an account of an actual activity, event, or problem containing some of the background and complexities actually encountered by a practicing person in the field.

Scope

Engineering case studies can be included at all levels of the engineering curriculum. The hardest part of using case studies is finding cases that fit with the class material. This, however, should not deter you from using the case method, as there are many texts on case studies. Professors, other TAs, or contacts in your industry are other great resources for finding cases. With a little work, it should not be too hard to find a good case for any class.

Strategies

Students are usually given written material regarding a case, and are asked to read it and answer a series of questions pertaining to various aspects of the case. The students can be required to work either individually or in groups. The following are some tips to remember when using a case study:

- The case study questions may increase the amount of work the students have to do outside of class. Care must be taken to balance this extra workload with other homework assignments.
- When using case studies found in the library, do not stick to using the questions given with the case. Generate new questions that fit the topics covered in class directly.
- While the questions that are assigned form the basis of the discussion, be prepared with other questions to guide the discussion.

- The goal of the class's use of the case should be kept in mind at all times. Keep the discussion from drifting away from this goal.
- Above all, be thoroughly prepared for the discussion. Poor preparation will lead to frustration among the students.

Example: Design Change for a Walkway

The following case study was used in a design course taught in the University of Wisconsin-Madison College of Engineering. The case helped students discuss how changes in a design during manufacturing and construction can affect the safety of the overall design. The students considered the following problem:

> *The on-site engineers want to know if they can change part of a design to ease construction. As head engineer, would you allow the change? Why or why not?*

The case material described the failure of the walkway in the Hyatt Regency Hotel.

The collapse occurred due to a shear failure of the beam when a large group gathered on both the upper and lower walkways to watch a band playing in the courtyard below. In the first design, the beam holds the weight of only one of the walkways. In the modified design, the section of beam between the rods carries the weight of both walkways. The failure occurred in this section of the beam. The TA did not disclose the effects of the design modification while handing out the case materials; the students were simply asked whether or not they would allow the change, and to include any calculations to support their claims.

About a quarter of the class decided that they would allow the change, while the rest decided that they would not. However, the students who would not allow the change produced a variety of answers, not all of which were close to the right answer. These students who produced the right answers were asked to describe the failure mechanism to the rest of the class. The TA graded the students' work more on the amount of thought put into the case rather than on getting close to the correct answer. The whole exercise took only one full class period in addition to the time required for grading.

Teaching with Case Studies[53]

Managing a Case Assignment

- ☑ Design discussions for small groups: three to six students are an ideal group for setting up a discussion on a case.
- ☑ Design the narrative or situation so that it requires participants to reach a judgment, decision, recommendation, prediction or other concrete outcome. If possible, require each group to reach a consensus on the decision.

- ☑ Structure the discussion. Provide a series of written questions to guide small group discussion. Pay careful attention to the sequencing of the questions. Early questions might ask participants to make observations about the facts of the case. Later questions could ask for comparisons, contrasts, and analyses of competing observations or hypotheses. Final questions might ask students to take a position on the matter. The purpose of these questions is to stimulate or guide (but not dictate) participants' observations and analyses. The questions should be impossible to answer with a simple "yes" or "no."
- ☑ Debrief to compare group responses. Help the whole class to interpret and understand the implications of their solutions.
- ☑ Allow groups to work without instructor interference. Be comfortable with ambiguity and with adopting the non-traditional roles of witness and resource, rather than authority.

Designing Case Study Questions

Cases can be more or less "directed" by the kinds of questions asked—these kinds of questions can be appended to any case, or can be a handout for participants unfamiliar with case studies.

- ☑ What is the situation — what do you actually know about it from reading the case? (Distinguishes between fact and assumptions, which is critical for understanding)
- ☑ What issues are at stake?
- ☑ What questions do you have — what information do you still need? Where and how could you find it?
- ☑ What problem(s) need to be solved? (Opportunity to discuss communication versus conflict, gaps between assumptions, and sides of the argument)
- ☑ What are all the possible options? What are the pros and cons of each option?
- ☑ What are the underlying assumptions for [person X] in the case, and where do you see them?
- ☑ What criteria should you use when choosing an option? What does that mean about your assumptions?

Guided Design Projects[54]

Introducing Practical Design Experience in Classrooms

Guided design projects aim to bring practical design experience into the classroom. Often conducted over a period of a semester, the projects give students an opportunity to work in a team environment, apply theory learned in the classroom, and learn about industrial design methodologies.

Scope

Guided design projects are appropriate for any level, but are often reserved for the junior and senior levels. As with the case method, choosing a project is typically the hardest part. Using guided design projects usually requires a lot of preparation by the TA. One of the best ways to have students appreciate the industrial design methodology is to have them redesign existing systems or products.

Strategies

The following are some tips to remember when using a guided design project:

- ☑ Realize that the product is not as important as the thought processes that go into determining a design. It is not important that the students determine an optimal design. What is important, however, is that they experience the design process.
- ☑ Starting before the semester begins, determine the scope of the projects and the goals for the class. It is important that the scope of the project is reasonable; care must be taken to ensure that the students are not overloaded.
- ☑ When possible, divide the design into sections. This spreads the work and the grading duties over the semester. Design teams of two or three students are frequently used. This allows for in-depth projects, reduces the grading load of the instructors, and promotes interaction among the students.

Brainstorming

Encouraging Creativity

The brainstorming technique is widely used in industry and academia to encourage participants to generate ideas in an unhindered manner. In an academic context, brainstorming encourages students to participate actively in idea-generation exercises and experience the benefits of a multi-dimensional approach to analyzing problems or solutions. Asking interpretive questions, rather than "yes/no" questions, leads to productive brainstorming.

Scope

The brainstorming technique is applicable to all levels of the engineering curriculum and to all teaching scenarios – labs, lectures or discussion sections. It is especially useful in design courses since it calls for a multiple-answer, multiple-dimension methodology rather than the usual single-answer approach to problems. The brainstorming technique can be implemented in a number of different ways as follows:

- *Structured*

  The whole class is given a topic to discuss and each student is called upon to contribute an idea. The advantage of this method is that all students participate, and the more vocal students tend not to dominate the discussions. The disadvantage is that the discussions usually do not flow freely as in an unstructured session, and can make some students feel pressured and uncomfortable.

- *Unstructured*

  Students are allowed to contribute ideas as and when they think of them. This approach allows for a freer flow of ideas and a more relaxed environment. The drawbacks to this approach are that it can lead to the students not responding at all, or to a few students dominating the discussion.

- *Group*

  This is a structured approach. The class is broken into small groups, and each group presents its ideas after an allotted amount of time. The advantage of this method is that the students are likely to be more at ease and willing to express their ideas. The group work also promotes synergy and communication among the students. One obvious drawback to this method is that it more time-intensive than the other two methods.

Guidelines

The following guidelines should be followed with any of the above methods:

- ☑ Make sure that everyone agrees on the question or topic of the brainstorm. Write it down on a chalkboard, for example, or give handouts.
- ☑ Never criticize students' ideas or allow students to criticize each other.
- ☑ Do not allow students to reject ideas initially. Ideas should not be weeded out until the end of the brainstorming. This keeps the solution path from becoming prematurely narrow.
- ☑ Write every idea down. Use a flip chart, blackboard, overheads, Post-It™ notes, or other visual methods.
- ☑ Use the words of the speaker when recording; do not interpret.

Group Work[55]

General Information about Using Groups

Another important aspect of student learning is group work. Making students work together in groups is beneficial and can be used in a variety of contexts. Groups might be created in class or out of class, around projects or weekly homework assignments. Because group composition can have a significant impact on group functioning, you should use a variety of methods to create groups. Allowing students to create their own groups should be done sparingly, as it can consciously or unconsciously be used to create or reinforce social group differences within the class.

Communicate to students the importance of learning to work together. Collaboration, rather than individual effort, is the norm in many STEM fields. Bring in guest speakers from academia, government or industry to discuss the importance of teamwork with your students.

Reasons for using cooperative groups:

- To facilitate student learning
- To improve interpersonal relationships among students
- To foster students' responsibility for their own learning and the learning of others
- To prepare students to work in groups in their future careers

Types of groups:

- Lab groups
- Homework groups
- Problem solving groups
- Study groups

Methods of assigning groups:

First, consider your learning objectives. Then, choose a method from the list below that is most appropriate. If you do not have well-defined objectives for group work, you may want to rethink your use of groups.

- Make heterogeneous groups across certain characteristics such as gender, race, area of residence, and/or level of achievement in a particular discipline, to improve interpersonal relationships among students.
- Ask students to draw a piece of paper with a group number from a bag.

- Allow students to form their own groups.

In addition to being aware of group formation issues, pay attention to the length of time students remain in the same group, particularly if the group is not working together well. It is essential that you address process issues when students work in groups, and some class time should be allocated in the planning of the course to discuss group process issues throughout the semester. You should help students determine a way to provide feedback to one another about group process and dynamics and a way to keep you aware of within-group functioning. Feedback is particularly important for identifying social identity characteristics that might be a source of problems in groups and for figuring out how to address problems satisfactorily. The following guidelines may be useful for addressing group process.

Create Roles

When groups are used, make sure that the same individuals do not always put themselves in the position of leadership. Assigning students to roles (e.g., recorder/notetaker, reporter, or moderator), or asking students to rotate roles, should reduce the occurrence of this problem.

Challenge Assumptions

Be ready to challenge assumptions that groups will either be aided or hindered by having certain kinds of students in their group. One way to reduce the likelihood of such assumptions manifesting themselves in group work would be to inform the class that each individual brings a different combination of strengths and weaknesses into the group work context and that students should not make assumptions about what these might be. Group exercises that identify the specific resources that each group member contributes can be useful in the early stages of group formation. It is also important to inform students of your availability to discuss group process problems that the groups themselves are unable to address successfully.

Prevent Isolation of Group Members

If students are shunning a classmate during small-group activities because their classmate is gay and they are homophobic, you have a responsibility to intervene on behalf of the excluded student.

To monitor group interaction, break a large project into smaller units and work with the groups to achieve their goals step-by-step. Dividing the project can make it easier to observe student-student interactions. This technique is known as "scaffolding."

You may need to make an extra effort to reduce the chances that a student who is different from the majority of the class will feel isolated (an African American student in a predominantly Caucasian class; a male in a predominantly female class; an openly gay, lesbian or bisexual student in a class composed predominantly of heterosexuals, etc.). For example, if students are shunning a classmate during small-group activities because their classmate is gay and they are homophobic, you have a responsibility to intervene on behalf of the excluded student.

Even when guidelines have been established for participation and responsibilities within groups, problems may arise. It is essential to act quickly when they do. You could begin by reviewing the guidelines for group work. An initial change (if students are forming their own groups) would be to assign individuals to groups and make sure each individual within the group has a role. Another option would be to put students in pairs. It is more difficult to exclude an individual when there are only two participants. If all else fails, it would be important to set up a meeting with the excluded student. Together, you could generate a variety of actions that could be taken to improve the classroom climate. This meeting would be a show of support for the student. While it is important to solicit student input, you cannot expect the student to have the time or experience to solve the problem. If efforts are made to improve the situation and little change occurs, you might speak to your co-instructors or to an administrator.

Group Work in an Introductory Science Laboratory[56]

Introductory science laboratories in the university setting often have to rely on groups to efficiently use the resources that are available.

Science classrooms are often equipped with tables around which the students sit, rather than the traditional rows of individual desks. My classroom had four square tables with seating for one person on each of the sides. This led to the students forming their working groups the first day. The students tended to disperse themselves evenly around the available tables as they came in. For instance, the first four people that came in tended to pick four different tables. As more students came in, they also distributed themselves randomly and evenly among the tables. To some extent, this distribution resulted in grouping of different personalities together because the students did not know each other when they entered the class. I thought that the students might regroup as the semester went on, but instead they much preferred to use the same space for the entire semester regardless of how they interacted with their group. The random distribution of individuals among the groups was very much what I had hoped for.

> *I found that the longer my lecture was, the more students were apt to tune out what I was saying.*
> *– Robert Cooper, Graduate Instructor, Michigan State University*

Teaching assistants often have a short (sometimes long) lecture containing information for the students before they start the lab. I found that the longer my lecture was, the more students were apt to tune out what I was saying. It is important to start out the class with everyone on the same wavelength. I started my labs with announcements pertaining to the class, and then solicited questions pertaining to labs I had handed back and labs they had just handed in. This allowed me to answer questions the students had in front of the entire class. It also allowed the students to see that others in the class had the same questions they did. Then, I briefly explained the new lab and handed it out. The students worked on the labs in their small groups.

In labs of 15 to 20 people, group size is best limited to four or five people. I found that three people tended to work independently, and more than five allowed for someone in the group to avoid participating. Groups of four or five were large enough that students were apt to articulate an idea, thinking that someone else would have similar thoughts. The groups were also small enough that students who tended to shy away from asking questions in a large group would pose those questions to peers in the smaller group setting. Group size will depend upon the total size of the class, the amount of available lab materials, and, interestingly, the size of the tables. Don't squish eight people around a table meant for four, even if you don't have enough lab supplies. Wait until one group is done and rotate the materials, or the students, about the room. In the same vein, don't spread four people around a table meant for ten. This is no longer a group, but becomes four individuals.

I worked more closely with specific groups if they were struggling with the material and the rest of the class was not. It is essential when working with groups that the GSI (graduate student instructor) recognize the dynamics of each group. For example, one group consistently seemed to comprehend the material and move quickly through the lab. With this group, it was important to check that everyone was working at the same pace. If four students understood the material and one did not, the less-rapid student tended to copy down answers, so as not to slow down the rest of the group. To check understanding as I worked with the groups, I asked each person if they understood the material. I posed some challenging questions for each member of the groups that were working particularly quickly. This allowed me to slow down the groups, make them think about the consequences of the work they were doing, and find out if individuals were having problems with the material. I looked for group dynamics from across the room as well, checking that all members were engaged in the discussion at some point. If they were not, I intervened to tie the group back together with some questions.

> *It is essential when working with groups that the GSI [graduate student instructor] recognize the dynamics of each group.*
> *- Robert Cooper, Graduate Instructor, Michigan State University*

A student that was having trouble with the material could also slow the group down and make the lab unproductive. Often, if one student fell behind, the others in the group tended to "goof off" while waiting for the slower student to catch up. I tried to stimulate these groups by asking questions from the lab to the students who had finished a particular section. I also posed questions to draw the students back into a group as a whole. For example, I would ask students who had finished a section how they did a certain part. Then I asked them if they could explain how they thought through the problem, and how that might help a hypothetical slower student in the group. Not only did this help any slower students develop ideas and additional points of view, but it also made the others think again about their own work. After I did this exercise once or twice, I found that students took responsibility for the others in their groups.

I found that, when in groups of four to five, the students want to be at the same level as others in their group. Students that understood the material, or to whom I had explained the material so that they understood, wanted to show their peers that they had gained knowledge. It was a status symbol to show the others they had this knowledge. The students who didn't understand the material looked at their peers and said, "If s/he can do this, I must be able to do it." These two attitudes had an amazing effect on group dynamics. Suddenly, I had groups of teachers and students in my class. The students with a good grasp of the ideas wanted to pass on their knowledge, and the students who were confused wanted to understand the material. Not only did this make it easier for me to teach, but it made the students more comfortable working with one another as well.

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>
> *– Robert Cooper, Graduate Instructor, Michigan State University*

Although it certainly was a great feeling to have the groups working on their own, I never lost contact with any group for more than 10 minutes. If I had been fielding questions from three of my four groups, I either quickly checked on the fourth group, or sometimes just told them that I saw them working well (or not well) so they knew I was still interested in their progress. If the lab had kept the students busy for the entire period, I tied the entire class back together at the end by asking again for general questions and previewing what we would be doing in the next session.

Lab groups are an integral part of lab science. The necessity of working in groups is often brought on by limited supplies, but groups can also be an effective teaching structure. The small-group format allowed me to get closer to the students and gave them opportunities to ask and answer questions of each other. I don't feel that instructors should shy away from using this structure; instead, they should try to tailor their classes for effective use of small groups.

Working in lab groups is an opportunity for students to learn to work with other students and learn to talk and share ideas about the material. This group experience helps prepare them for teamwork later in their careers.

Science Labs[57]

The goal of most laboratory classes is to make a connection between the theoretical elements of a discipline and the practical aspects of technical performance. In general, there are three objectives which should be considered when teaching a lab:

- Practice and mastery of specific technical skills, such as preparing an agar plate or setting up an apparatus for measuring chemical weight changes
- Mastery of the skills of the scientific process, such as observation, classification, inference, hypothesis development, and design of methods of investigation
- Experience of abstract concepts in a concrete manner, such as measurement and comprehension of free energy or angular momentum

On another level, the lab experience gives students a more intimate knowledge of the discipline and a more intense involvement in the processes of scientific inquiry. Lab work also encourages cooperation and teamwork among students, thus reinforcing the social aspect of learning. Together, all of these elements can contribute to a positive and exciting learning environment.

The Role of the Lab Instructor[58]

The lab instructor has a very important role in helping students to feel good about their lab experience. How a lab instructor handles his or her responsibilities can make the course either enjoyable or painful for the students. A lab instructor may have many responsibilities: leading discussion, teaching in laboratories, monitoring safety, grading, proctoring during exams, and more. Lab instructors also have an especially important role in helping to make undergraduate students' education a quality experience. In fact, in most lab settings, the lab instructor has significant influence on the students' experiences.

> *It is important to help students realize that everyone learns from mistakes, and working through the mistakes as a group often leads to a much deeper level of understanding and thought for everyone.*

Because lab instructors work with students in small groups and on a one-to-one basis during office hours, they have the opportunity to provide the personal touch, individual feedback, and encouragement that students need to succeed in a science laboratory class. They have the opportunity to get to know the students as individuals, to know their strengths and weaknesses, to understand how they think, and to challenge them to improve.

Another important aspect of lab instructors' work is helping students develop higher-level thinking skills and problem solving skills through active involvement, guidance and feedback. To do this, they must not always be so quick with answers that students end up relying on them to do their thinking. Lab instructors' role is to ask the kinds of questions that will help students think through problems and learn how to solve them. To do this, they must create the climate needed for students to feel safe enough to ask and answer questions and to participate in discussions. Often, students don't participate because they are afraid they will be wrong and look stupid in front of the lab instructor and their peers. It is important to help students realize that everyone learns from mistakes, and that working through the mistakes as a group often leads to a much deeper level of understanding and thought for everyone. Sometimes, a lab instructor will be asked questions for which he or she is not sure of the answers. It is fine to use the phrase, "I don't know." One could use this as a teaching opportunity and tell the class how one would go about finding an answer. In any case, the lab instructor should find the answer and explain it to the class during the next lab period.

One other important role of a lab instructor is that of being a team member with other lab instructors and the faculty member in charge of the course to help make the course better. It helps everyone if lab instructors collaborate with each other, sharing and discussing successes and any problems that might arise. One way of communicating with others teaching the course is through e-mail. It is also important to provide a communication channel between the students and the supervisor and/or faculty instructor in charge of the course. Instructors are not always in a position to know what students are finding difficult or how the lectures could be more helpful to students in understanding the concepts.

What Do the Students Need to Know?[59]

Too often, we feel that the only things we should teach or are allowed to teach in a science lab are the specific sets of facts or techniques that are outlined in the lab manual. However, if this gives the students an impression of science as a restricted and procedure-bound set of steps, they never develop any of the higher-order skills that are required of professionals in the field. There are a number of additional concepts that a lab instructor should keep in mind as being of importance to expose students to. The lab instructor should take every opportunity to introduce these concepts in discussions and presentations in and out of the laboratory.

Critical Thinking

As mentioned above, the ultimate aim of training students in a science lab is not merely to fill them with facts, but to help them learn how to approach and analyze a problem. How do we formulate questions and establish facts? How do we determine the meanings of observations? How do we reason? Teaching students to think critically can be approached by helping them develop an awareness of the steps one goes through in a scientific investigation.

How to Ask Questions

Scientists spend their time trying to answer questions for which there are no known answers. But the quality of the research and importance of the answer often depends on how good the question is. Asking insightful and meaningful questions is a skill that must be learned. Part of the students' training in the laboratory should include practice in asking questions. Encourage the students to ask questions for the sake of forming the questions and analyzing how it is done.

One exercise that can be used in lab – or as an outside exercise to encourage students to develop their skills at inquiry – is the 20-Question Game. Have the students sit quietly in the lab or elsewhere and think about the course work or their surroundings. Each student should write down 20 questions that come to his or her mind about the body of knowledge encompassed by the course. It is not important whether the question has a known answer. The goal is to give the students practice in using their imaginations.

> *…the quality of the research and importance of the answer often depends on how good the question is.*

Afterwards, one can discuss their questions with them individually or in groups. What types of questions did they ask? Usually their questions will fall into a few categories: "why" questions, "how does it work" questions, structure and function questions, "what if" questions, and "where does this fit" questions. What are the advantages and difficulties of each kind of question? How would one go about answering them? Would the answer to the question say anything significant about the nature of patterns in the discipline? Can the question be feasibly answered, given the available time and resources? Are the questions generalizable? With practice, the students will go from asking questions like, "Why is this tree taller than that one?" and "How many molecules are in the human body?" to "What are the factors that control plant growth?" and "How do cells select which molecules cross membrane boundaries?" In a short while, the students will find that questions come more freely to mind, and that many of them could lead to productive research programs.

How to Answer Questions

Finding the answers to questions is the physical labor of doing science. As one talks to students and answers their questions, it is useful to tell them about the process by which the answers were found.

The basis of most scientific investigation is an observation about a pattern. A tentative explanation for the pattern can be given, and is called a hypothesis. Before the explanation can be accepted, however, it must be tested. A prediction is made about what should be seen under other circumstances or at a different time, if the explanation is correct. The results of the experiment may be as predicted, and therefore support the explanation and add to our confidence in it, or may not be as predicted and indicate that the explanation needs to be revised. Ideally, this process is repeated until the results from all the experimental tests can be explained by only one hypothesis. It is important to explain that one can never prove a hypothesis; one can only fail to disprove it. Science advances because, as techniques are improved, additional predictions can be tested to further refine hypotheses.

This process of investigation serves as a heuristic model to describe the thought processes that go on when a person tries to answer a question. Another set of skills necessary to answer questions are those involved in running a valid experiment. The details will vary from discipline to discipline, but virtually every experiment involves first defining the terms with which you are describing the system, identifying the variables and assumptions, identifying the possible sources of error, and determining what is already known about the system. A possible step involves comparing an experimental group to a control group, which should differ from the experimental group in only one variable. Experiments can be either manipulative, in which the scientist causes the difference between the two groups, or natural, in which advantage is taken of natural differences between groups. The strength of the experiment is influenced by both sample size and replication of experimental and control groups.

Reward independent thinking, even if it leads to a wrong answer. The ability to think creatively is much needed in the sciences –don't squelch it. Just point out the lines of evidence (perhaps not yet known to the student) which indicate another, more correct answer.
– Margaret Bickmore, Geology TA

How to Deal with Numerical Data

Students often want to record their results on paper towels or scrap paper. These are easily lost and are hard to keep organized. The data should be recorded in a lab notebook or on data paper that can be easily stored safely in a binder and with column headings and descriptions that will allow the data to be interpreted later. A lab instructor should encourage the students to treat all their data as important, even if they think they already know what the answer will be, and to make their measurements with all the accuracy allowed by their equipment. They should also think in advance about how they will analyze their data. This will help them to avoid collecting data that cannot be analyzed or that do not answer their question.

When the students analyze their data, they should keep in mind the question that they are trying to answer. Students often analyze their data in a particular way only because they saw that the data could be put together in that fashion, and not because it addressed their question.

When the students analyze their data, have them keep in mind the question that they are trying to answer.

In some of the introductory labs, many students will not yet have studied statistics, and therefore the lab instructor can only expect a minimal amount of sophistication in how they analyze their data. The best that many students will be able to do to simplify their data will be to calculate mean values. However, the lab instructor should take the opportunity to tell them about the need for statistics to estimate the uncertainties in their results. Even though a hypothesis can never be proven, a statistical test can tell how likely it is that results could have occurred by chance or error. In more advanced labs, most students will come in with knowledge of calculus and statistics, but the lab instructor may have to help them learn to apply it to the material of the lab. Again, the lab instructor should know the math background of his or her students.

The hardest thing for many students to learn is how to interpret their data. It is important for lab instructors to introduce them to the ideas of causation and correlation. For example, in the life sciences, we are usually interested in discovering what the cause of a pattern is, but can often only determine whether or not two variables are correlated with one another. Also, a lab instructor should remind them of the complexity of their experiments. Not only is any pattern likely to be influenced by more than one variable, but each variable is likely to have multiple effects.

Encourage your students to display their data in ways that are easily interpreted by other people, such as in graphs or tables. This will help them learn to communicate their results and will often give them new ideas about what their data might mean.

How to Communicate

Both written and oral communication skills are important in every profession. However, in our experience, many students feel that the quality of their scientific writing is not important. It is essential to discourage this view. Clear and effective communication skills are vital, no matter what profession students plan to enter. A lab instructor should make every effort to comment constructively on both students' basic writing skills and their ability to effectively communicate their scientific ideas on paper.

Also, a lab instructor should encourage students to practice their oral communication. Students often have difficulty expressing themselves verbally in science classes because of the large number of new terms (this is especially true of introductory labs). At first, it can be useful to get them to think about what they are trying to say in non-technical language. Then, the lab instructor should provide the scientific terminology for their ideas. In this way, students improve their ability to interact verbally and to use scientific terminology to increase the precision of their communication.

Scientific communication also involves the use of visual aids. Getting students to draw diagrams of concepts and specimens that they observe in the lab can enhance their learning. If they are required to give formal oral presentations in the laboratory, the lab instructor can help them to organize and use illustrative slides and overhead projections.

Everyone is Capable of Doing Science

A difficult thing to convey to students is that everyone is capable of doing science. Students' lack of confidence in their scientific abilities often results from high school science courses in which they were taught only to memorize facts and formulae. As a result, they never learned that science is as much a way of thinking as it is a body of knowledge. These students can often be helped by using examples of hypothesis formulation and testing that relate to non-laboratory situations. For example, people often go through the process of formulating, testing, and revising a hypothesis whenever they burn a cake in the oven or their car refuses to start. Students can use these examples to recognize that they already know how to do science, and that by taking a science course they are simply broadening their awareness of the world around them.

The First Day[60]

It is essential that the lab instructor put in careful thought and planning for the first lab class.

This is the time to set the tone for the rest of the term. It is a time to get acquainted with the students and for the students to get acquainted with the lab instructor and each other. For instance, a lab instructor may want to know students' majors, math background, computer expertise, and similar courses taken previously, including in high school. If lecture and lab are not connected as one course, the lab instructor will want to know which students are taking the lecture course concurrently. One could have students put this information on an index card.

The lab instructor should help the students understand the relationship of the laboratory section to the overall course.

If the lab instructor plans to have the students work in groups, it is important to form the groups and have some way for them to get acquainted with each other. The first day's experiment may be simple but require group members to work together so they begin to get to know each other as collaborators and resources.

The lab instructor should help the students understand the relationship of the laboratory section to the overall course, and point out that most of the experiments are intended to illustrate basic ideas that underlie the fundamental concepts of science. He or she should briefly review the types of experiments the students will be performing, emphasizing that, because it will generally be necessary for the lab instructor to present essential information and instructions at the beginning of each session, they should be sure to arrive for class on time. The lab instructor should show the students the laboratory facilities and give them a few minutes to become familiar with their surroundings.

Much of the lab philosophy, protocol and policies should be written on a handout in addition to being discussed in class.

It is especially important to distribute a handout that specifies policies and guidelines. This is important for several reasons: it gives the lab instructor and students a written record, provides information for students joining the class after the first day, and documents course policies in case disputes arise later. The lab instructor can bring copies to subsequent classes for those who don't attend on the first day. In courses with multiple sections where the instructor provides a course-wide lab handout, it is still important to have your handouts for lab section(s). Students will appreciate knowing their lab instructor's personal outlook and expectations for lab, and the lab instructor can give more details about his or her sections (expected quiz dates, due dates for assignments, embellishments on discretionary points, etc.) Experienced lab instructors in the department are a good resource for finding out what specifically needs to be emphasized or explained explicitly on the first day.

Other things that should be communicated on that first day include:

Safety:

- The importance of laboratory safety
- The safety rules (e.g., when to use goggles)
- What to do in the event of an emergency

Lab Expectations:

- The general ground rules for the proper handling and storage of supplies and equipment
- The importance of clearing work areas and cleaning and storing equipment before the end of each session because the laboratory must be used by subsequent classes
- The name and source of the manuals and supplies the students will be expected to purchase
- The general type of preparation required for each session

Student Concerns:

- The need to communicate any requirements for special consideration because of physical or other impairments on the first day; students may be timid about volunteering this information unless given the opportunity to do so

Grading:

- The overall grading policy
- Expectations regarding independent and collaborative work

- The format for notebooks and reports the students will be expected to prepare; sample notebooks and reports can be useful
- Guidelines on what is expected for lab reports; the lab instructor may consider distributing an example of a good lab report and discussing its good points with the students

Policies:

- Any ground rules regarding:
    - Attendance policies
    - Late report policies
    - Lab make up policy
    - Cheating and plagiarism policies
    - Breakage and replacement policies

Future classes:

- The assignment for the next laboratory session

Class policies should be presented in the context of basic professionalism (e.g., "Companies require their employees to be on time.")

Planning and Running a Laboratory[61]

With preparations finished, everything is in place and ready to go for the students. Here are some recommended activities for structuring the lab period.

Going into the lab early and writing a brief outline on the board

This helps keep students focused, helps pace the work, and is especially important for classes that might have multiple ongoing experiments. The lab instructor can include pertinent announcements (review and exam dates, assignments due) to avoid spending too much time on these during class. He or she may wish to put this information on a handout for the students.

Beginning the lab on time

Waiting for everyone to show up only encourages latecomers. Consistent promptness on the lab instructor's part can remind everyone to arrive on schedule.

Summarizing the results of the previous week's lab

Providing summaries is important for continuity throughout the semester.

Giving a brief introduction to this week's lab

The lab instructor can give any announcements, answer questions about lecture, and introduce the lab concisely.

Demonstrating any tricky techniques or apparatus and pointing out the location of special materials

The lab instructor should gather the class close for this and make certain everyone can see and hear. While encouraging questions, he or she should also ask additional ones to monitor understanding. This will help the lab instructor to avoid explaining the same thing ten times in the first half hour. This is a good time to have students form lab groups.

Interacting with students

Taking an active role with students improves their learning. The lab instructor should learn and use students' names, and try to interact with everyone during the period. Moving throughout the room can be helpful, as can checking notebooks and making suggestions, eavesdropping on discussions, or reading over students' shoulders. This way, one can be readily available when questions come up and can steer students in the right direction if they've gone off course.

> *Students will usually not ask questions. Constant circulating by the TA is needed… I would either ask how it was going, what certain results showed (concepts proven), or if there was another way to do something. Nine times out of ten doing this provoked good, thoughtful questions.*
> *- Christina DeGnore, Physics TA*

It is important to let students take responsibility for learning, de-emphasizing the "teacher as expert" model. One purpose of a laboratory section is to teach students how to learn through experimentation; in other words, how to do science. It can be hard to know where to draw the line between effective hands-off teaching and letting the class drift aimlessly. It is useful to develop and follow a procedure for encouraging students to be their own resources. For example, one might require students to pose their question to three other students before asking the instructor.

Pacing student progress

Many lab periods are too short, and students will not finish unless the lab instructor keeps the class on track. He or she should tell the students what parts of the lab absolutely must be completed during the period. The lab instructor can also periodically announce what they should be working on at a given time. It is important to try to keep the class at roughly the same point, while recognizing that students work at different rates. The lab instructor can aid groups that are lagging behind schedule. For those who finish early, he or she may encourage review of the material or discussion of additional questions, and expect some socializing.

Providing a sense of closure and cleaning up

With students working at various paces, some people will finish before others, and it can be difficult to gather everyone's thoughts at the end of a chaotic period. However, a good conclusion reinforces learning. It is a time for reflection and processing observations. The lab instructor can post results on the board and let the students draw their own conclusions. If time is short, this can begin when most people have finished. One should allow sufficient time for cleaning up. Before leaving, it is crucial to check that all equipment and utilities such as gas, air and water outlets have been turned off.

Being familiar with equipment

There may be a large variety of equipment in use during the semester, some of which will probably be unfamiliar to the lab instructor. However, all of it will be new to the students, and the instructor will be teaching them how to use it. A general knowledge of each piece is very useful (e.g., its purpose, how to turn it on, in what units measurements are given, and whether a manual exists.). One should find out how to do any calibrations for the lab and be familiar with the functions of all controls. It is a good idea to tape over any controls which students should not change, or encourage them to do so for the sake of the experiment and check that they are properly reset at the end of lab. One should remember to allow sufficient warm-up periods for equipment that needs it.

> *Encourage collaboration. The students will learn as much from hashing things out with each other as they will from you – if not more.*
> *- Margaret Bickmore, Geology TA*

One of a lab instructor’s most frustrating responsibilities may be to maintain enough functioning equipment in the classroom. Many teaching laboratories are equipped with outmoded machines that have been abused for years. Should the lab instructor teach in a large course, the vast numbers of students sharing equipment virtually guarantees that equipment may be miscalibrated or non-functioning by the time the class uses it. If students cannot work on the lab for a few minutes while equipment is being replaced or repaired, one can use the time to work on calculations or discuss available results.

Being absolutely certain about how to get help when equipment fails

It is essential to not leave defective equipment in the room. The lab instructor should make sure it is turned in for repair.

Safety Procedures[62]

The lab instructor is responsible for ensuring that undergraduate students are appropriately supervised at all times during the laboratory session. He or she must make students aware of all safety procedures and must enforce these rules. If there is an accident, lab instructor conduct may be a factor in any legal proceedings. For example, if a lab instructor neglects to wear safety goggles after having told students to wear theirs, this poor example may put the lab instructor at fault for any accident that occurs.

Disciplinary practices and lab instructor authority vary widely from department to department and even from course to course. Be sure these protocols are made clear. Before the session begins, the lab instructor should consult with his or her supervisor to determine the approved departmental procedure for disciplining students who are disruptive or who neglect to observe safety procedures.

Troubleshooting [63]

Working through the lab in advance will allow the lab instructor to determine any portions that may be particularly confusing or have greater potential for "creative interpretation" by students. However, even the best written, best prepared experiment may not work, especially given the challenges imposed by inexperienced undergraduates. The following actions may lessen the probability of unusual results and/or compensate for lack of results:

- Experienced lab instructors can share information about the teaching history of the lab. What "horror stories" can new lab instructors avoid, and how?
- It is important to pay attention to problems and difficulties that occur during the class. If several students appear to be having trouble with a particular aspect of the experiment, it may indicate a general lack of understanding by the students, or a lack of clarity in the protocol. This is a good time to stop the class and clarify the problem. The lab instructor should know what material students are covering in the lecture course. In some cases, students may not have had the appropriate lecture yet.
- The lab instructor should explore why equipment and procedures are not working, and should not be afraid to ask graduate students or the lab supervisor.
- Using data from other sources – other students in the class, other sections, even trial data from the prep session – can aid in troubleshooting.
- When a lab does not work as expected, students can write up a "failure analysis" instead of the lab.
- Students can also redo the experiment later.

Summary of Science Labs

Science labs are intended to:

- ☑ Teach students specific technical skills
- ☑ Help them understand scientific and technical processes
- ☑ Ground abstract concepts in reality

The lab instructor's role is to:

- ☑ Encourage students and help them develop higher-order thinking skills, such as:
    - Critical thinking
    - Asking and answering questions
    - Handling data
    - Effective communication

Points that should be communicated on the first day include:

- ☑ Safety information
- ☑ Expectations
- ☑ Accommodation policies
- ☑ Grading policies
- ☑ Other ground rules

Elements of effective teaching include:

- ☑ Using the blackboard effectively
- ☑ Beginning the class on time
- ☑ Giving a summary of the previous lab and an introduction to the next one
- ☑ Demonstrating any important or difficult techniques
- ☑ Not pretending to know the answer to every question
- ☑ Encouraging students to take responsibility for learning
- ☑ Pacing student progress
- ☑ Providing a sense of closure at the end of the lab
- ☑ Knowing how to get help when equipment fails

- ☑ Being familiar with your legal responsibilities
- ☑ Running through lab procedures ahead of time
- ☑ Clarifying problems as they arise
- ☑ Communicating with other lab instructors and the professor

Labs offer an opportunity for students to learn about effective group work. Your role as an instructor is to help facilitate positive group dynamics.

- ☑ Evaluate your progress.
- ☑ Provide students with clear expectations for their lab reports and give them detailed comments on their performance.

Teaching Outside the Classroom[64]

Effective teaching does not only occur in the classroom. Tutoring sessions, office hours, and other forms of out-of-class contact can be great ways for you to get to know students, understand their background and perspectives, and help them succeed. Students who succeed are usually those who attend class regularly, ask questions, and come to office hours and problem-solving sessions. They study outside class both alone and in study groups, seek to understand methods and overarching principles or concepts rather than specific answers, teach or tutor others, and discuss concepts informally with their fellow students. You should discuss the importance of learning outside the classroom with your students.

Tutoring[65]

> *Tutoring may be needed and expected, especially in introductory courses. It should be provided before difficulties become overwhelming.*

In light of the varied backgrounds and expectations of students in most classrooms, it is essential that you know how to refer students to academic and non-academic resources they are likely to need. Tutoring may be needed and expected, especially in introductory courses. It should be provided before difficulties become overwhelming. Accordingly, you can be most helpful by providing students with opportunities for obtaining prompt feedback, comments, and assessment (short papers, quizzes, lab reports, etc.) early in the term.

You also may have to help students revise their expectations of tutoring. Students from different backgrounds might view tutoring in very different ways. Some students come to tutoring for clarification, some expect to be shown how to get the answers, and others come to be shown the answers. It is important to explain what tutoring and problem sessions can do; what topics, questions, and problems will be addressed; and what students should do before, during, and after such sessions. Scheduling tutoring sessions before or after assignments are due emphasizes the function of the sessions.
A stigma can be attached to seeking tutoring services because needs or other deficiencies in preparation are viewed as signs of innate inability. However, the students who do best are usually those who take advantage of every learning situation. Tutoring and problem-solving sessions should be portrayed positively. These sessions are frequently the best opportunities for students to get to know the teachers and to see how they think. Methods and answers are important, but personal contact can be crucial to a student's success.

> *A stigma can be attached to seeking tutoring services because needs or other deficiencies in preparation are viewed as signs of innate inability.*

Office Hours[66]

Because students often are reluctant to visit a teacher's office to discuss their concerns, some teachers have held their office hours in more public places such as bars, which they thought would provide a more relaxing and informal atmosphere. Although these teachers reported that more students came to see them as a result of holding their office hours in these places, some students avoided meeting their teachers in this situation. Consider, for example, a female student whose male teacher holds office hours in a bar. The teacher has put the student in a situation which may make her feel that she is the object of the teacher's personal, rather than professional, attention (which undermines the intellectual climate goals of the university). Therefore, while you might consider offering some office hours in non-traditional places, be careful that you choose places that are neutral and non-threatening to students. Coffee shops and student unions are some possible settings which are less intimidating.

Also consider the time that you hold your office hours. Vary the time when you meet with students, so that students who are busy or employed may find a time which works with their schedules. Offer appointments to students whose schedules do not match yours. If you hold office hours late in the afternoon or in the evening, when there are few people in the building, you may make students feel uncomfortable. Female students may be concerned for their personal safety if they have to walk to your building after dark, or if they have to enter a darkened building. When meeting with students, keep your door open or slightly open unless there is a third person in the room. By keeping the door open, you create a less personally threatening atmosphere in your office.

> *One way to make students more comfortable coming to your office is to offer both group and individual office hours.*

One way to make students more comfortable when they come to your office is to offer both group and individual office hours. Students who typically avoid one-on-one office meetings with their professors might be more likely to come if they know that all the attention in the meeting will not be focused on them. For example, if you find that several students make similar mistakes in their homework sets, suggest that they come to your office together, if possible, for a mini-tutorial in a workshop format. The students will realize that they are not alone in their difficulties and can learn from each other's mistakes.

Teaching Students to Solve Problems[67]

When a student comes to you during office hours and says, "I don't get it," what do you do? The most natural response might be to try to find out more specifically what the student doesn't understand and explain or demonstrate it to the student. Although the student may also expect this, it may not always be the most effective way to help. The student may listen to the explanation or watch as you work the problem and may go away thinking that he or she understands the problem. While that particular problem may be understood, when asked to do a similar problem on a test, the student may have difficulty. There are a variety of reasons a student might be having difficulties in solving problems. The sources and types of errors a student may have are listed below.

Sources and Types of Errors in Problem Solving[68]

Inaccuracy in reading

- Reading the material without concentrating strongly on its meaning
- Skipping one or two unfamiliar words
- Losing one or more facts or ideas
- Failing to reread a difficult section
- Starting to work on the problem before reading all of the material

Inaccuracy in thinking

- Not placing a high premium on accuracy (above speed or ease)
- Not taking enough care in performing some operation
- Interpreting words or performing operations inconsistently
- Not checking a formula or procedure when feeling some uncertainty
- Working too rapidly
- Drawing conclusions in the middle of a problem, without sufficient thought

Weakness in problem analysis; inactiveness

- Failing to break a complex problem into parts; not using the parts that are understood to figure out more difficult parts
- Not drawing upon prior knowledge and experience when trying to make sense of ideas which are unclear
- Failing to use the dictionary or other resources when necessary to understand the problem
- Not actively constructing a representation of ideas on paper (when a representation would have helped in understanding the material)

Lack of perseverance

- Lacking confidence and giving up easily

- Choosing an answer based on a superficial consideration of the problem (having a feeling of what might be correct – guessing)
- Solving the problem in a mechanical manner, without much thought
- Reasoning the problem part-way through, giving up, and jumping to a conclusion
- Using the "one shot" approach to solving the problem and, when that doesn't work, giving up

How You Can Help

Students need training and practice in problem solving. To make teaching during office hours more effective, you must make it student-oriented instead of teacher-oriented. Your goal is not to show them the answer to a specific problem, but to teach them how to go about solving problems and how to think while solving problems. In other words, you must get students to do the thinking and help them modify their thinking by having them slow down and use good problem solving techniques. Some ways to get students to slow down and reflect on their thinking processes when solving a problem are:

- ☑ Have students read the problem aloud and tell you what is needed to solve it before they start to work.
- ☑ Get students to work problems while "thinking out loud." Encourage students to constantly talk about what they are doing and why. This will slow down the thinking process and make it more explicit and more accurate. You can often help students check their own reasoning and find their own mistakes by having them express exactly what they know about a problem. Comments or questions that can help students clarify their thinking might include some of the following:
  - What are some possible ways you might go about solving this problem?
  - Tell me what you know about the problem.
  - How might you break the problem into small steps?
  - Please tell me how you got from step one to step two.
  - What are you thinking right now?
  - I don't understand your reasoning behind that step. Will you please explain?
- ☑ Sometimes you will find it necessary to model good problem solving techniques. You may have to demonstrate how you would go about reading and understanding a question before starting to work the problem. You may show how you would solve the problem, making the process clear to the student, (e.g., working step-by-step; backing up if necessary when things don't work out;

breaking a complex problem into parts and using the parts you understand to figure out the more difficult parts; actively constructing a representation of ideas on paper; etc.). After modeling the process, require students to work through a similar problem to make sure they understand the process.

Advising and Extracurricular Activities[69]

Meet with students informally.

Frequent and rewarding informal contact with faculty members is the single strongest predictor of whether or not a student will voluntarily withdraw from a college (Tinto, 1989). Ongoing contact outside the classroom also provides strong motivation for students to perform well in your class and to participate in the broad social and intellectual life of the institution. In addition to inviting groups of your students for coffee or lunch, consider becoming involved in your campus orientation and academic advising programs, or volunteering to speak informally to students living in residence halls or to other student groups.

Encourage students to come to office hours.

Of course, all students can benefit from the one-to-one conversation and attention that only office hours provide. In addition, students who feel alienated on campus or uncomfortable in class are more likely to discuss their concerns in private (Chism, Cano, & Pruitt, 1989).

Don't shortchange any students of advice you might give to a member of your own gender or ethnic group.

Simpson (1987) reports the following unfortunate incident. A Caucasian male faculty member was asked by a female African American student about whether she should drop an engineering class in which she was having difficulties. Worried that if he advised a drop, he might be perceived as lacking confidence in the intellectual abilities of African American women, he suggested that she persevere. Had the student been a white male, the professor acknowledged, he would have placed the student's needs ahead of his own self-doubts and unhesitatingly advised a drop.

Advise students to explore perspectives outside their own experiences.

For example, encourage students to take courses that will introduce them to the literature, history, and culture of other ethnic groups (Coleman, n.d.).

Involve students in your research and scholarly activities.

Whenever you allow students to see or contribute to your own work, you are not only teaching them about your field's methodology and procedures, but also helping them understand the dimensions of faculty life and helping them feel more a part of the college community (Blackwell, 1987). Consider sponsoring students in independent study courses, arranging internships, and providing opportunities for undergraduates to participate in research. Also, encourage students to attend professional society meetings.

Help students establish departmental organizations.

If your department does not have an undergraduate association, encourage students to create one. Your sponsorship can make it easier for student groups to obtain meeting rooms and become officially recognized. Student organizations can provide peer tutoring and advising as well as offer social and academic programs. In fields in which women and certain ethnic groups have traditionally been underrepresented, some students may prefer to form caucuses based on their gender or cultural affinities (for example, women in architecture). Research by the Institute for the Study of Social Change (1991) has documented the importance of associations for students of color as a basis for collective identification and individual support.

Provide opportunities for all students to get to know each other.

For example, research shows that both African American and Caucasian students would like greater interracial contact. African American students tend to prefer institutional programs and commitments, while most Caucasian students prefer opportunities for individual, personal contacts (Institute for the Study of Social Change, 1991).

Summary of Teaching Outside the Classroom

- ☑ Assist students in learning problem-solving methods.
- ☑ Mentor students and encourage their interest in your field.
- ☑ Make office hours accessible to students by accommodating their personal concerns (e.g., night safety) and schedule conflicts.
- ☑ Encourage students to seek tutoring as needed.

Overcoming Misconceptions[70]

Societal Attitudes and Science Anxiety

A commonly held view is that understanding simple phenomena is possible for the average person, but that understanding science is not. Some students are easily discouraged by their inability to grasp the concepts presented in class immediately. Teachers need to have the patience and the conviction to convince students that they can learn. How a teacher relates to students can either reinforce or counteract stereotypical societal attitudes. For example, inappropriate stereotypes can be endorsed by faculty members by their choices of pronouns, their examples of scientists and nonscientists, how they select students to answer questions, what questions they ask of different students, and how they listen to or interrupt students who are asking or answering questions.

Inclusive Practices

According to Gibbons (1993), the most important factor in helping students of color to succeed in mathematics and science courses is the personal interest and support of a faculty member. He suggests inviting students from underrepresented groups to join research labs, being sensitive to concerns of minority students, and being aware that they may need help in networking.

> *The most important factor in helping students of color to succeed in mathematics and science courses is the personal interest and support of a faculty member.*

Many students respond best to people with whom they can identify. For some, this means same-gender role models with similar cultural and ethnic backgrounds. Visitors to class and appropriate examples can help to diversify the role models presented in a class. However, Caucasian faculty members can serve as mentors to students from underrepresented groups, male faculty members can serve as mentors to women students, and vice versa.

Science teachers can help create positive attitudes toward science and mathematics by encouraging students to work together on research projects. Departments can establish discipline-specific study rooms, where students can find and interact with others in their courses. These can also serve as a meeting place for small study groups, or as a place where teaching assistants conduct “office hours” to assist students.

Most students respond positively to activities such as visiting a professor’s research lab, hearing about a professor’s research, and viewing video clips of scientists explaining new discoveries. It can be very helpful to incorporate such activities into an introductory science class, despite the temptation to get on with the “real” science or the pressure to cover all of the content.

One option is to begin each class with a brief discussion of an event in the day's newspaper or a news broadcast that has a scientific component, so that students appreciate the connections between science and everyday experience. Many faculty members have found it fruitful to spend just a few minutes early in the semester sharing the results of their own work with the students in a way that explains the creation of ideas, development of proposals and receipt of funding, data collection and testing, paper writing and peer review, and presentation at meetings. Those teachers who serve on committees that advise government bodies or act in other public service roles can share stories of these efforts to show how science and society interact.

For a number of reasons, students do not always feel comfortable asking for help. To address this issue, you can request meetings with students as problems arise, or make office hour meetings part of the course requirement (e.g., each student will meet with you after receiving his or her grade on the first assignment). The latter is an ideal method because it allows you the opportunity to meet one-on-one with every student. It also removes the stigma that may be attached to going to office hours.

It is essential that instructors have high expectations for all students. For example, if a student earns a grade of C or lower, you should inform the student of the need for a meeting to discuss his or her performance. If students are absent, you should show concern about their absence when they return by asking if things are all right with them. If there are repeated absences, you should request a meeting with the student to discuss the situation. It is important for you to make initial contact with students; however, at some point, students need to take the initiative.

If a specific type of writing is expected for a given class, it may be useful to assign a short, un-graded assignment early in the term to identify students who may need additional assistance in meeting that particular writing standard. It is misleading to equate students' writing skills with their intellectual ability. Students have varying degrees of experience with "academic" writing. You have a responsibility to be explicit about what is expected and share with students examples of good writing done by other students. You should also alert students early on of their need to improve their writing and should suggest resources to them.

Misconceptions as Barriers to Understanding Science[71]

> *Even some of the best students give the right answers, but are only using correctly-memorized words. When questioned more closely, these students reveal their failure to understand fully the underlying concepts.*

Teachers can be astonished to learn that, despite their best efforts, students do not grasp fundamental ideas covered in class. Even some of the best students give the right answers, but are only using correctly-memorized words. When questioned more closely, these students reveal their failure to understand the underlying concepts fully. Students are often able to use algorithms to solve numerical problems without completely understanding the underlying scientific concepts. Mazur

(1997) reported that students in his physics class had memorized equations and problem-solving skills, but performed poorly on tests of conceptual understanding. Nakhleh and Mitchell (1993) studied 60 students in an introductory course for chemistry majors. In an exam which paired an algorithmic problem with a conceptual question on the same topic, only 49 percent of those students classified as having high algorithmic ability were able to answer the parallel conceptual question.

Besides offering students information and helpful examples, we must show them the reasoning processes that lead to algorithms and conceptual generalizations. Inclusion of conceptual questions on tests is another way to emphasize the importance of this aspect of problem solving. In many cases, students have developed partially correct ideas that can be used as the foundation for further learning. However, many students have not developed an appropriate understanding of fundamental concepts from the beginning of their studies, and this shortcoming can interfere with subsequent learning.

Types of Misconceptions

A familiar example from elementary school is students' understanding of the relationship between the earth and the sun. While growing up, children are told by adults that the "sun is rising and setting," giving them an image of a sun that moves about the earth. In school, students are told by teachers (years after they have already formed their own mental model of how things work) that the earth rotates. Students are then faced with the difficult task of deleting a mental image that makes sense to them, based on their own observations, and replacing it with a model that is not as intuitively acceptable. This task is not trivial, for students must undo a whole mental framework of knowledge that they have used to understand the world.

The example of the earth rotating rather than the sun orbiting the earth is one of many that teachers refer to collectively as misconceptions. Misconceptions can be categorized as follows:

- *Preconceived Notions*
  Preconceived notions are popular conceptions rooted in everyday experiences. For example, many people believe that water flowing underground must flow in streams because the water they see at the earth's surface flows in streams. Preconceived notions plague students' views of heat, energy, and gravity, among others.

- *Nonscientific Beliefs*
  Nonscientific beliefs include views learned by students from sources other than scientific education, such as religious or mythical teachings. For example, some students have learned through religious instruction about an abbreviated history of the earth and its life forms. The disparity between this widely held belief and

the scientific evidence for a far more extended pre-history has led to considerable controversy in the teaching of science.

- *Conceptual Misunderstandings*
  Conceptual misunderstandings arise when students are taught scientific information in a way that does not provoke them to confront paradoxes and conflicts resulting from their own preconceived notions and nonscientific beliefs. To deal with their confusion, students construct faulty models that usually are so weak that the students themselves are insecure about the concepts.

- *Vernacular Misconceptions*
  Vernacular misconceptions arise from the use of words that mean one thing in everyday life and another in a scientific context (e.g., "work"). A geology professor noted that students have difficulty with the idea that glaciers retreat, because they picture the glacier stopping, turning around, and moving in the opposite direction. Substitution of the word "melt" for "retreat" helps reinforce the correct interpretation that the front end of the glacier simply melts faster than the ice advances.

- *Factual Misconceptions*
  Factual misconceptions are falsities often learned at an early age and retained unchallenged into adulthood. If you think about it, the idea that "lightning never strikes twice in the same place" is clearly nonsense, but that notion may be buried somewhere in your belief system.

How to Break Down Misconceptions

Although vernacular and factual misconceptions can often be easily corrected, even by the students themselves, it is not effective for a teacher simply to insist that the learner dismiss preconceived notions and ingrained nonscientific beliefs. Recent research on students' conceptual misunderstandings of natural phenomena indicates that new concepts cannot be learned if alternative models that explain a phenomenon already exist in the learner's mind. Although scientists commonly view such erroneous models with disdain, they are often preferred by the learner because they seem more reasonable and perhaps are more useful for the learner's purpose (Mayer, 1987). These beliefs can persist as lingering suspicions in a student's mind and can hinder further learning (McDermott, 1991).

Recent research on students' conceptual misunderstandings of natural phenomena indicates that new concepts cannot be learned if alternative models that explain a phenomenon already exist in the learner's mind.

Before embracing the concepts held to be correct by the scientific community, students must confront their own beliefs along with their associated paradoxes and limitations, and then attempt to reconstruct the knowledge necessary to understand the scientific model being presented. This process requires that the teacher:

- Identify students' misconceptions.
- Provide a forum for students to confront their misconceptions.
- Help students reconstruct and internalize their knowledge, based on scientific models.

Identifying Misconceptions

Before misconceptions can be corrected, they need to be identified. Many researchers and teachers have compiled lists of commonly encountered misconceptions. A number of professional societies have developed conceptual tests which allow you to identify students' misconceptions. Additionally, small group discussions and office hours provide effective forums for identifying student misconceptions. With practice and effort, a teacher can learn to probe a student's conceptual framework (often by simply listening) without resorting to authority or embarrassing the student. Mazur has found a way to help students check their conceptual frameworks even within the large lecture format. Hake (1992) has used introductory laboratory exercises to help students test their conceptual bases for understanding motion. Essay assignments that ask students to explain their reasoning are useful for detecting students' misconceptions. These essays and discussions need not be used for grading, but rather can be used as part of the learning process to find out what and how your students are thinking.

> *With practice and effort, a teacher can learn to probe a student's conceptual framework (often by simply listening) without resorting to authority or embarrassing the student.*

Misconceptions can occur in students' understanding of scientific methods as well as in their organization of scientific knowledge. For example, students in a science class will often express disappointment that an experiment did not work. They do not fully understand that experiments are a means of testing ideas and hypotheses, not of arriving at an expected result. To the scientist, an experiment yields a result which needs to be interpreted. In that sense, each experiment "works," but it may not work as expected.

Helping Students Confront Their Misconceptions

It is useful to review and think about possible misconceptions before teaching a class or laboratory in which new material is introduced. Use questions and discussion to probe for additional misconceptions. Students will often surprise you with the variety of their preconceptions, so be careful to listen closely to their answers and explanations. You can help students by asking them to give evidence to support their explanations and by revisiting difficult or misunderstood concepts after a few days or weeks.

Misconceptions are often deeply held, largely unexplained, and sometimes strongly defended. To be effective, a science teacher should not underestimate the importance and the persistence of these barriers to true understanding. Confronting them is difficult for the student and the teacher.

Some misconceptions can be uncovered by asking students to sketch or describe some object or phenomenon. For example, one might ask students to sketch an atom before doing so on the board. Even students who have a strong high school background might show a small nucleus surrounded by many electrons circling in discrete orbital paths, much like the solar system. By asking students to draw their own model first and then share their answers with the class, a teacher can identify preexisting models and use them to show the need for new models.

Helping Students Overcome Their Misconceptions

Strategies for helping students to overcome their misconceptions are based on research about how we learn (Arons, 1990; Minstrell, 1989). The key to success is ensuring that students are constructing or reconstructing a correct framework for their new knowledge.

Helping students to reconstruct their conceptual framework is a difficult task, and it necessarily takes time away from other activities in a science course. However, if you decide to make the effort to help students overcome their misconceptions, you might try the following methods:

- Anticipate the most common misconceptions about the material and be alert for others.
- Encourage students to test their conceptual frameworks in discussion with other students and by thinking about the evidence and possible tests.
- Think about how to address common misconceptions with demonstrations and lab work.
- Revisit common misconceptions as often as you can.
- Assess and reassess the validity of student concepts.

Common Difficulties and Misunderstandings[72]

Problems of Terminology

1. Confusing the technical meanings and the ordinary meanings of words.
Some scientific terms have technical meanings that are very different from their common sense meanings. For example "spontaneously" in chemistry does not mean "very quickly" or "all by itself" – it means "without net input of energy." Students may be more familiar with the common English definition. Therefore, they might think that spontaneous reactions occur rapidly and/or without an enzyme. This type of difference

between technical and ordinary meanings often leads to a lot of confusion because the TA, text author or lecturer is using the term in the technical sense, while the student is using the non-technical, commonsense meaning. Even when the student tries to use the term correctly, s/he is often confused by the connotations that the word has in common usage.

Another example: The teacher asks "Does burning destroy matter?" and the student says "Yes." The teacher groans and thinks the student is an idiot. But the student is not; s/he is using the term "destroy" in its ordinary English sense, and the teacher is using it in its technical physics sense. If the teacher's house burns down, the house will certainly be destroyed (in the English sense), even though the atoms that were in the house have not been altered.

2. Using words that have technical meanings and not realizing it.
Some ordinary English words are used as technical terms, as explained above, but experienced scientists (such as graduate students and lecturers) are so used to using these words that they often forget that these words have special meanings. So the scientists don't define the terms, and then are surprised when the students don't know what they mean. For example, what is a "strain" of bacteria? Do all bacteria of the same strain have the same genes and/or alleles? Are the genes in the same order? Are all bacteria of one strain of the same sex? A graduate student who works with bacteria will consider these questions so obvious that s/he will not realize that the answers are not common knowledge.

3. Getting confused when using similar but not identical terms.
Certain pairs of terms seem to be difficult to distinguish – for example, "gene" and "allele," as well as "chromosome" and "chromatid." There are many such sets of terms that are very similar in meaning and that are often used sloppily even in scientific writing (and speech). To make it worse, some of these terms are synonyms in common speech, such as "inhibition" and "repression." A good way to clear up confusion is to compare and contrast; compare what the two terms have in common and contrast their differences.

Other types of common conceptual difficulties

1. Finding unlikely and/or complex solutions when ordinary, simple ones will do.
There is a saying in medical school: "When you hear hoof beats in Central Park, you don't think of zebras." In other words, when you hear hoof beats in the park, it is probably a horse, even though it could be a zebra. A person who thinks it is probably a zebra does not understand the situation. When solving problems, always look for the "horse" – the simple, obvious solution – before you starting worrying about the "zebra" – the possible, but unlikely solution. Students often come up with very improbable (but possible) answers, and don't understand why their answers are unlikely or why unlikely answers are not as good. Usually their problem is a lack of general background

– if you don't know much about New York City, you might not realize that horses are relatively common there and zebras are rare.

2. Not seeing how the parts relate to each other or to the whole.
Students often understand what certain items are, or what they do, but do not understand how the items relate to each other, or how the details relate to the big picture. For example, students may understand the structure of DNA, that genes are made of DNA and that chromosomes carry genes, but they may have trouble figuring out how the DNA fits in the chromosome. (How many copies per chromosome? How many strands? What's a strand?) As another example, students may understand how DNA is replicated, transcribed, and translated, but they still may not understand how a gene controls a trait. So you may need to explain "up" or "down" how the parts relate to the whole – up, how the item under discussion fits into something bigger, and down, how the item is made of smaller things. For example, if you are discussing genes, you should be prepared to go "up" to chromosomes, genomes, traits, etc., and "down" to DNA, codons, nucleotides, and bases.

How to Speak and Avoid Misunderstandings

1. Use a picture or diagram in addition to words.

2. Avoid pronouns and use nouns instead.
Don't say "it" – say "mRNA" or "gene" or another specific noun. You should be careful not to use too many vague pronouns yourself, and you shouldn't let the students fall into that habit either. For example, suppose a student says, "The gene is transcribed and then it goes to the cytoplasm and is translated, which uses tRNA and mRNA." Now the student may or may not understand how genes are expressed, but you can't tell whether s/he knows or not, because "which" could mean transcription or translation. In this example, the student may know the correct answer and just be using poor English by accident, or the student may not know and be using unclear language on purpose to hide his or her confusion. Alternatively, the student may not even realize that s/he is unclear in his or her own mind. So, if you want to express yourself clearly, use as many nouns and as few unclear pronouns as possible, even if it sounds a little repetitious. Encourage students to talk in nouns too.

3. Before you start to explain a topic or problem, find out where the student is stuck.
This will save you from wasting time and energy explaining things that are clear and will allow you to zero in on the real problem.

4. Explain a short piece of a problem at a time.
Don't go on until (a) you are sure that everyone understands what you explained and (b) you are sure that you need to explain the rest. For part (a) asking "Does everyone understand?" doesn't usually get a satisfactory answer. You have to look at the students' faces or ask a question about what you have just said to find out if they

understand. For part (b) you may discover that you don't have to explain the whole thing because the part you just explained was the only hard part and the student has now become "unstuck." (See point 3 above.)

5. If you don't know the answer, go look it up.
Look it up for next time, or look it up right on the spot if you have the right book and can figure it out right away. You aren't expected to know everything, but you are expected to be able to figure student questions out eventually.

6. When a student asks a specific question, try to answer it without going over a lot of background material, unless it seems necessary.
If a student asks you to explain hydrogen bonds, don't start with atomic structure. Assume s/he knows what electrons and covalent bonds are, and proceed from there. If there is any question about where to start explaining, ask the student. (See point 3 above.)

Part Three:
Teaching-As-Research:
Continually Improving Your Teaching

Part Three: Teaching-as-Research: Continually Improving Your Teaching[73]

Like science, technology, engineering and mathematics (STEM) research, improving teaching and learning is a dynamic and ongoing process. Accurately determining what students have learned is at the core of improving teaching and learning. This is a research problem to which STEM instructors can effectively apply their professional skills.

> ***Teaching-as-Research*** *is the deliberate, systematic, and reflective use of research methods to develop and implement teaching practices that advance the learning experiences and outcomes of students and teachers.* (http://cirtl.net)

Conceptual steps in teaching-as-research are:

1. Learning foundational knowledge. (What do we know about the teaching practice?)
2. Creating objectives for student learning. (What do we want students to learn?)
3. Developing a hypothesis for practices that may achieve the learning objectives. (How can we help students succeed with the learning objectives?)
4. Defining measures of success. (What evidence will we need to determine whether students have achieved learning objectives?)
5. Developing and implementing teaching practices within an experimental design. (What will we do in and out of the classroom to enable students to achieve learning objectives?)
6. Collecting and analyzing data. (How will we collect and analyze information to determine what students have learned?)
7. Reflecting, evaluating, and iteratively changing teaching methods. (How will we use what we have learned to improve our teaching?)

This section focuses on two aspects of teaching-as-research; assessment of student learning and evaluation of one's own teaching. However, as the conceptual steps above indicate, teaching-as-research involves applying scientific methods to the entire teaching process.

Ideas that can be used in teaching-as-research are included throughout this resource book. We addressed steps 1-3 in Parts 1 and 2 of this volume. Part Three provides strategies and tips to address steps 4-7. We focus on both student assessment and instructor self-evaluation.

As with other types of research, it is essential to assess the progress of the teaching "experiment" throughout the course. Don't wait until the end of the semester to find out whether students are learning in your class. Mid-semester evaluations can give you information you need to adjust your course content. Such evaluations, coupled with end-of-the-semester questionnaires, can help to continually improve your course.

STEM instructors who use the teaching-as-research concept enter a continuous process of discovery and change that can benefit all students and can last throughout their careers.

Assessing Student Performance

Establishing Objectives for Assessment[74]

Solid course organization is essential for effective communication with students, meaningful grading, and relevant assignments and exams.

The first step in organizing your course effectively is listing your goals. The following questions can be helpful in generating a set of objectives for your course.

- ☑ What do you want your students to comprehend by the end of the course?
- ☑ What skills do you want them to master?
- ☑ What level of depth of knowledge do you want them to attain in each facet of the subject?
- ☑ What degree of problem-solving ability and intellectual independence do you want to foster?
- ☑ How much do you want your students to know about practical applications?

Once you have decided on your objectives, you can design your course around them. This includes exams, assignments, labs, lectures, discussions, and course evaluation. When appropriate, provide multiple ways for students to demonstrate knowledge. For example, along with traditional tests and papers, consider group work, demonstrations, portfolios, and presentations as options.

Undergraduates know that their academic performance will determine their future career path, so they are under pressure to excel. Often, students in introductory science courses are overwhelmed by the quantity of information they are expected to assimilate. They are not sure whether the textbook material, the lecture notes, or the homework assignments are most representative of what they need to learn for the exams.

Improved communication can make STEM courses more accessible for undergraduates. If you make your expectations clear to students at the beginning of the course and confirm them by using a consistent assessment method, students will feel much less intimidated by the course and will respect you as a teacher. They will also focus their efforts on what you think is important for them to learn.

Students who already doubt their own competence or feel socially isolated benefit greatly from coherent course design. A female student who knows that she is not the "stereotypical scientist" may be more easily discouraged by instructors who adopt a "sink or swim" attitude towards their students and do not communicate clearly with them.

Defining your course goals also allows you to challenge your students to develop their higher-order problem-solving skills, which are essential in the workplace. As you write down your goals, you can organize them from low-level objectives (basic knowledge) to intermediate objectives (competency) and higher-level objectives (mastery). Then, when you write your exams, you can provide some questions of each type on the exam.

Do not surprise your students with difficult mastery questions on the exams unless they have already solved highly challenging problems in their problem sets. As a general rule, exams should be somewhat easier than homework assignments. Students become discouraged and resentful if they are asked to solve problems which they are not prepared to handle.

As a general rule, exams should be somewhat easier than homework assignments.

Scientific ability is a combination of aptitude and training. With proper preparation, undergraduates can learn to think creatively about science problems. Asking higher-level questions in introductory courses can keep bright students motivated and interested in the sciences.

Assessment Primer [75]

An Introduction to Assessment - the Basics

- What is assessment?
- Why do it?
- Why do it in a particular way?

This document addresses these important questions and provides an introduction to the basic concepts and terminology surrounding assessment. The discussion builds toward a generalized model for course development. Central to this discussion is the following key precept: *Assessment drives student learning.*

What Is Assessment?

Assessment is more than grades.

To many, the word "assessment" simply means the process by which we assign students grades. Assessment is much more than this, however. Assessment is a mechanism for providing instructors with data for improving their teaching methods and for guiding and motivating students to be actively involved in their own learning. As such, assessment provides important feedback to both instructors and students.

Assessment is feedback for both instructors and students.

Assessment gives us essential information about what our students are learning and about the extent to which we are meeting our teaching goals. But the true power of assessment comes in also using it to give feedback to our students. Improving the quality of learning in our courses involves not just determining to what extent students have mastered course content at the end of the course; improving the quality of learning also involves determining to what extent students are mastering content throughout the course.

Thus, in addition to providing us with valuable information about our students' learning, assessment should assist our students in diagnosing their own learning. That is, assessment should help students "become more effective, self-assessing, self-directed learners" (Angelo & Cross, 1993, p. 4). Various classroom assessment techniques (CATs) have been developed with this in mind.

Assessment drives student learning.

The types of assessment usually performed in first-year science, technology, engineering, and math (STEM) courses – giving students tests – merely inform students about their grade, or ranking, after they have received instruction. In addition, these common testing techniques – which typically test for fact-based knowledge and algorithmic problem solving – tell our students that this is the type of knowledge we think is most important. That is, we appear to value the understanding of concepts at a relatively low level.

Given that this is the type of assessment STEM students most frequently encounter, and that it will eventually lead to their final course grades, students learn to study the course content in an expeditious way that allows them to succeed in passing many first-year STEM courses without necessarily developing deep understanding of concepts. It is assessment that drives students' learning.

In fact, assessment drives student learning whether we want it to or not. The consequences of relying upon our "tried and true" assessment methods are profound; these assessment methods may actively promote superficial learning. If we wish to actively steer what our students learn, and how well they learn it, we must (1) actually decide what we want our students to take away from the course, and (2) choose our classroom assessment techniques appropriately (Anderson & Sosniak, 1994; National

Research Council, 1996; Tobias & Raphael, 1997; Wiggins, 1998). The importance of setting course goals – articulating them and writing them down – cannot be overstated. Evaluating the extent to which we have attained our stated course goals is the primary motivation for why we "do assessment." Furthermore, ensuring that our assessment techniques can measure our stated goals is the reason for why we "do assessment in a particular way."

Why do assessment?

To evaluate attainment of course goals

For every course we teach, we make decisions about what we want our students to know and be able to do by the end of the semester. Though we might not always formalize these goals by writing them down, we still make decisions about the curriculum, the instructional methods, and the assessment techniques we will employ. In terms of curriculum, we decide which topics to cover, and how they connect with previous and forthcoming topics. We also decide which instructional methods we will use to deliver the curriculum – lectures, group activities, readings, homework assignments, etc. Similarly, we decide what assessment techniques we will use (e.g., multiple-choice tests). Thus, the decisions we make reflect our goals for the course whether we state them or not. It is important, therefore, to formalize course goals while the course is still in its planning stage.

Formalizing our goals is only the first step, however. We must also measure the extent to which we are attaining these goals. This is why we do assessment. Logically, we must choose classroom assessment techniques that are appropriately suited to measuring our particular goals. That is, we must align our assessment techniques with our stated goals.

Why do assessment in a particular way?

To align assessment with stated goals

The most commonly employed assessment technique in first-year STEM courses is the multiple-choice test. Such tests are usually most effective at measuring fact-based knowledge and ability to perform algorithmic problem-solving. If our stated goals are that students be able to recite facts and to solve simple algorithmic problems, then the chosen assessment technique is well aligned with the stated goals. However, if our goals include different student outcomes than these (e.g., an understanding of the scientific "process," a lifelong interest in the subject, the ability to critically analyze science in popular media, etc.), then this assessment technique will not provide useful feedback about attainment of these goals.

Furthermore, misaligned assessment techniques convey to students the wrong message about what we want them to take from the course. As suggested previously, an instructor's choice of assessment technique drives student learning (Anderson & Sosniak, 1994; National Research Council, 1996; Tobias & Raphael, 1997; Wiggins, 1998).

Concerns about assessment are not the only ones faced in the development and refinement of STEM courses; decisions about curriculum and instructional methods are equally important, and assessment plays a vital role in guiding these decisions.

Summary

Assessment is feedback for both students and instructors.

The perspective that has been advocated here is that we can use carefully constructed classroom assessment techniques as a means of determining whether or not we are meeting our stated course goals, not just for assigning our students grades.

For us, classroom assessment can help us answer the following questions:

- ☑ To what extent are my students achieving the stated course goals?
- ☑ How should I allocate class time for the current topic?
- ☑ Can I introduce this topic in a more effective way?
- ☑ What parts of this course are my students finding most valuable?
- ☑ How will I change this course the next time I teach it?
- ☑ Which grades do I assign my students?

For our students, classroom assessment answers a different set of questions:

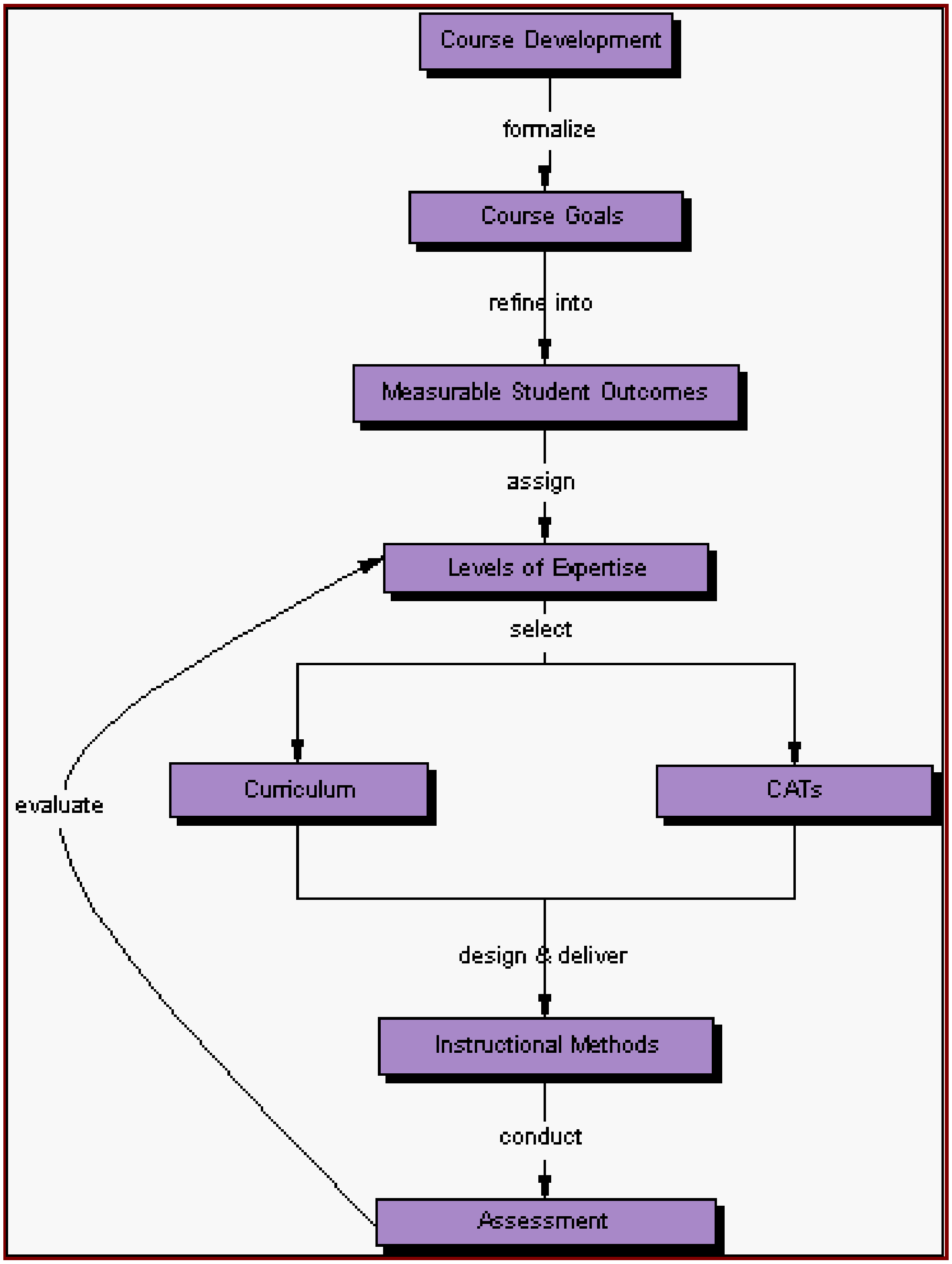
- ☑ Do I know what my instructor thinks is most important?
- ☑ Am I mastering the course content?
- ☑ How can I improve the way I study in this course?
- ☑ What grade am I earning in this course?

Answering these questions and others can inform and improve the quality of student learning in our classes.

A Charge to Change

We can not emphasize enough how important it is to actually write down your course goals and share them with your students. Our goals are what bind the course together (Figure 1). Our choices of curriculum , instruction, and assessment are all guided by – and held together by – our goals. Once your course goals are set, questions about instruction, assessment, and grading will be much more focused. This is a small step beyond the assessment strategies that most faculty are already doing; yet with a small investment in planning, the data acquired can provide valuable feedback for improving the quality of student learning. And ultimately, our students are what course development is all about.

Figure 1. - Road Map of Course Development.



Formulating Effective Methods of Assessment[76]

Students often complain about their grades when the basis for their assessment is unclear to them. Clear communication also makes courses more inclusive for students from underrepresented groups, such as international students, who might otherwise misunderstand unspoken expectations. Students' ability to "guess" what they will be assessed on does not indicate mastery of course content.

Day-to-day class activities and assignments should reflect the instructor's assessment method. This is not to say that the assessment must be a "regurgitation" of class work and readings, but it should fall within the same general framework of the course. Ungraded trial tests can be useful tools both to alert the instructor as to the students' abilities and to provide the students with an understanding of the assessment method.

There are many methods of grading. Numeric methods are not necessarily more "objective" than those that rely on written comments or holistic approaches. It is important for instructors to think through their grading philosophy and purposes before deciding on a grading scheme. Before selecting a grading method, it is also advisable to check relevant course or departmental policies.

Letter Grading

Letter grading should be familiar to anyone who has attended a traditional high school, college or university. Defining what constitutes each level of performance is the responsibility of the instructor.

Advantages

- Letter grades are convenient for determining levels of competence for future employment and advanced education.
- Letter grades provide feedback.
- Alternatives to letter grades may not result in more effective assessment.

Disadvantages

- Grades can be determined by mixing factors that have various weightings.
- They can divide students into discriminatory and often competitive groups.
- They can foster dependent, conforming, unimaginative behavior in students.
- Letter grades can emphasize hierarchy among students. This can have an adverse effect on learning.

Satisfactory-Unsatisfactory

Satisfactory-unsatisfactory systems are based on one cut-off point that determines whether the student has passed or failed the course.

Advantages

- This system can be more relaxed and less competitive.
- This system can provide a better atmosphere; students may be willing to take risks with the teacher.
- Cheating may be reduced.
- Some students do more work when freed from the pressure of a letter grade.

Disadvantages

- A passing grade does not distinguish among levels of competence.
- Some students may work less.
- It can be difficult to state level of mastery leading to a passing grade.
- A failing student is still under pressure.

Within the above parameters, a variety of approaches can be used to arrive at the letter grade or the satisfactory/unsatisfactory grade. A few of these are listed below, along with some of their relative advantages and disadvantages.

Mastery Approach

The mastery approach assigns a basic satisfactory/unsatisfactory grade to students based on their achievement of specified goals. In a mastery system, students are ordinarily allowed to take different amounts of time to accomplish a goal and to repeat tests or assignments without penalty until they achieve the desired outcome.

Advantages

- The grade is meaningful since it is tied to the student's performance level.
- When students know their goals, they may achieve them faster.
- The focus is on success, rather than on failure.
- This system tends to generate cooperation and may raise morale among teachers and students.

Disadvantages

- This approach is more time consuming.
- It can limit the freedom of teachers.
- Some teachers might be too exacting in their requirements.

Contract System

A contract system of grading involves the development of a written contract between the student and the instructor that specifies precisely what will be required to receive any given grade. The course syllabus is a good place to communicate this option.

Advantages

- This system can reduce anxieties since the student knows what is expected.
- It can reduce the role of personal judgment in grading.
- It encourages self-set goals.

Disadvantages

- There is a potential for overemphasis on quantity.
- There can be difficulty in measuring the quality of student activity.
- Ambiguity may exist in qualitative distinctions between grades.

Self-Evaluation

A variety of formats can be used. The significant difference in this form of grading is that the source of the evaluation is the student. Instructors can use self-evaluation by students to determine part or all of the course grade.

Advantages

- Self-evaluation can be a learning experience for the student.
- Students are usually fair, objective, and demanding of themselves.
- It encourages students to take responsibility.

Disadvantages

- It can be taken less seriously as the novelty wears off.
- It can be abused when students are not introspective.
- It can be abused under extreme pressure for grades.

Helping Students Succeed on Assignments and Exams[77]

Be sensitive to students whose first language is not English.

Most colleges require students who are nonnative speakers of English to achieve oral and written competency by taking ESL courses. Ask ESL specialists on your campus for advice about how to grade papers and for information about typical patterns of errors related to your students' native languages. For example, some languages do not have two-word verbs, and speakers of those languages may need extra help - and patience - as they try to master English idioms. Such students should not be penalized for misusing, for example, "take after," "take in," "take off," "take on," "take out," and "take over."

Assign group work and collaborative learning activities.

Students report having had their best encounters and achieved their greatest understandings of diversity as "side effects" of naturally occurring meaningful educational or community service experiences (Institute for the Study of Social Change, 1991). Consider increasing students' opportunities for group projects in which three to five students complete a specific task, for small group work during class, and for collaborative research among two or three students who develop instructional materials or carry out a piece of a research study. Collaborative learning can be as simple as randomly grouping (by counting off) two or three students in class to solve a particular problem or to answer a specific question.

Suggest that students form study teams that meet outside of class.

By arranging for times and rooms where groups can meet, you can encourage students to study together. Peer support is an important factor in student persistence in school, but students of color are sometimes left out of informal networks and study groups that help other students succeed (Pascarella, 1986; Simpson, 1987). By studying together, your students can both improve their academic performance and overcome some of the out-of-class segregation common on many campuses.

Give assignments and exams that recognize students' diverse backgrounds and special interests.

As appropriate to your field, you can develop paper topics or term projects that encourage students to explore the roles, status, contributions, and experiences of groups traditionally underrepresented in scholarly research studies or in academia (Jenkins, Gappa, & Pearce, 1983). For example, a faculty member teaching a course on medical and health training offered students a variety of topics for their term papers, including one on alternative healing belief systems.

When administering exams, permit all students extended test time by scheduling exams for a time longer than the standard class period and identify small group test sites near the classroom for students who need a quieter environment with minimal distractions.

The Why and How of Tests[78]

Ideally, tests measure students' achievement of the educational goals for the course, and the test items sample the content and skills that are most important for students to learn. Tests usually ask students questions about material that is most essential to the discipline. A well-constructed test measures a range of cognitive skills, not just students' recall of facts. However, it is unlikely "that research will ever demonstrate clearly which form of examination, essay or objective, has the more beneficial influence on study and learning" (Ebel & Frisbie, 1986). Your choice of examination form will need to take into account many factors such as the time available for students to take the test, the amount of time you have available to grade it, and what you wish to measure. Some goals and methods of testing, adapted from Fuhrmann and Grasha (1983) are:

- To measure knowledge (recall of common terms, facts, principles, and procedures), ask students to define, describe, identify, list, outline, or select.
- To measure application (solving problems and applying concepts and principles to new situations), ask students to demonstrate, modify, prepare, solve, or use.
- To measure analysis (recognition of unstated assumptions or logical fallacies and ability to distinguish between facts and inferences), ask students to diagram, differentiate, infer, relate, compare, or select.
- To measure comprehension (understanding of facts and principles and interpretation of material), ask students to convert, distinguish, estimate, explain, generalize, define limits, give examples, infer, predict, or summarize.
- To measure synthesis (integration of learning from different areas or solving problems by creative thinking), ask students to categorize, combine, devise, design, explain, or generate.
- To measure evaluation (judging and assessing), ask students to appraise, compare, conclude, discriminate, explain, justify, or interpret.

There are a limited number of standard formats for exam questions. Multiple choice questions can measure students' mastery of details, specific knowledge as well as complex concepts. Because multiple choice test items can be answered quickly, you can assess students' grasp of many topics in an hour exam. Although multiple choice test items are easily scored, good multiple choice questions can be challenging to write.

One of the best ways to identify useful wrong answers for multiple-choice items is first to ask the question in a free response format. When the free-response tests are graded, look for common errors or misconceptions and tally them. If what went wrong is not clear from a student's response, ask the student to explain how he or she went about answering the question when the papers are returned. Then use common errors as the wrong answers for multiple-choice questions.

After several years of this activity — less, if you share items with colleagues — you will have a sizable bank of good multiple choice questions, and will understand common misconceptions and errors well enough to construct suitable multiple-choice questions without going through the preliminary step of giving free-response items first (Herron, 1996).

Short answer questions can require one or two sentences or brief paragraphs. They are easier to write than multiple choice tests but take longer to score, and may not be as useful as essay exams to measure the depth of student understanding. Essay questions probe students' understanding of broad issues and general concepts. They can measure how well students are able to organize, integrate, and synthesize material and apply information to new situations. Unlike multiple choice tests, you can only pose a few essay questions in an hour. Further, essay tests are sometimes difficult to grade.

Problem solving forms the core of many STEM courses, and numerical problems are prominent on many exams in these courses. Students who successfully answer these test questions do not necessarily grasp the underlying concept (Gabel & Bunce, 1994). Traditional numeric problems can incorporate some sort of conceptual essay section which measures the students' understanding of the concepts involved as well as their ability to use algorithms to solve problems. Nakhleh and Mitchell (1993) offer a sample of multiple choice questions for a limited number of chemistry concepts, in which the answers are pictorial representations of molecular events. Although you may find it difficult to develop an appropriate set of possible answers, asking students to draw a picture of the phenomenon described in the numerical problem is a good way to test their conceptual understanding.

Keep in mind that novice problem solvers take longer to locate appropriate strategies than experienced problem solvers. As a rule of thumb, it could take students ten minutes to solve a problem you might do in two minutes, so plan your test length accordingly. There are several resources to help faculty members develop, administer, and grade exams.

Grading Lab Reports, Problem Sets, and Exam Questions[79]

Clarity and constructiveness are two principles to keep in mind when grading. This section offers a series of tips on effective grading and feedback.

Make Your Expectations Clear

It is essential to communicate your expectations to your students before the assignment is due. Be specific: discuss the goals of the assignment, your grading procedures, and guidelines for style and formatting. If students are unaware of the criteria for achieving a good grade, they are likely to make more errors. This will increase your grading time and may frustrate your students.

Use a Grading Rubric

Grading rubrics are tables. Each line in the table includes a description of a grading criterion and a check box to indicate whether the criterion has been met. There are many advantages to using rubrics:

1. Using rubrics keeps grading fair and reduces the influence of personality or other extraneous factors. To increase your objectivity, you can ask students to write their names on the back of the page.

2. Rubrics allow straightforward explanations of grading and easy comparisons of student performance.
3. Rubrics save time.
4. Students gain more information about areas in which they need to improve.

Correcting Student Errors

A good instructor can turn a mistake into a learning experience by responding with specific comments that do not criticize the student directly. Tell students:

1. Sources that they should refer to for more information,
2. Where their mistakes occurred,
3. The location of any logical gaps in their statements, and
4. Where any erroneous assumptions took place.

Students appreciate praise. Tailor the praise to the assignment, noting specific tasks that the student did well. Also, being given the opportunity to revise their assignments allows students to improve their skills and enhances their learning experience.

Grading For Large Classes

Grading for large courses presents unique challenges. The following tips will assist you in grading quickly and effectively:

1. Skim through students' answers and note common responses before grading.
2. Divide students' work into piles based on quality, to make your grading more consistent and efficient.
3. Alphabetize the assignments before recording the grades.
4. Take regular breaks. Set a timer if necessary.
5. When you have graded half the assignments, go back and look at your first attempts. Is your grading consistent?

Grading Checklist[80]

☑ Develop your grading policy thoroughly beforehand, announce it at the beginning of class, write it on the syllabus, and stick to it. Know ahead of time how you will handle late homework, makeup exams, etc. Avoid modifying policies during the term.

☑ Incorporate plenty of opportunities for assessment. This will avoid unnecessary pressure and will allow for some mistakes.

☑ Keep old exams to pass out to students in the future, as reviews before tests or as homework problems.

- ☑ Consider grading based only on mastery of material and not on personality or perceived effort.
- ☑ Avoid competition between students; this may generate animosity and a poor learning environment. Emphasize learning over grades.
- ☑ Keep students informed of their progress throughout the term. Return the first assignment before the drop/withdrawal deadline.
- ☑ Consider allowing rewrites on papers, problem sets, and exams; establish your policy before class begins.
- ☑ Look over five to ten exams before you actually start grading, to see how the test went and to sort out your standards. If possible, grade question by question, not exam by exam. This promotes consistency. If many do poorly on an exam, schedule an exam for the following week to retest the class.
- ☑ Place encouraging comments on a test or paper to convey respect for what the student attempted to accomplish, and praise for what he or she did accomplish.
- ☑ Acknowledge and reinforce the strengths of students' work; prompt students to recognize shortcomings and options; and provide suggestions for improving performance. Also, provide feedback that helps students learn from their "mistakes" and position themselves to become more effective in the future.
- ☑ Keep accurate records of grades. Record numerical grades, rather than letter grades, when possible. Maintain complete grading records, including graphs of the results of each exam, so that you can spot problems in any of your tests.

Grading Specific Activities[81]

Laboratory activities involve aspects of reasoning, teamwork, experimental design, data acquisition and recording, data analysis, discussion, interpretation, and reporting. One way of grading labs (Joshi, 1991; Kandel, 1989) is to assess the following:

- ☑ Understanding of the results, whether or not they agree with expectations
- ☑ Decision-making skills based on both expected and unanticipated results (application of theory)
- ☑ Method of recording, presenting, and analyzing data; observations and results (the notebook and final report)
- ☑ Performance of physical manipulations (technique)

Rondini and Feighan (1978) describe a chemistry lab in which they give students at the end of each lab a numerical score for specific attributes, such as the product yield, equipment setup, handling of chemicals, purity of product, time to completion, technique, and safety procedures. These scores are added to the grades for their lab reports and notebooks. Thus, students know quickly what aspects of their lab techniques need improvement and can use this information as a catalyst for change. Joshi (1991) asks students to prepare and submit their lab reports online. The computer checks and grades the quality of input data; performs and displays the necessary calculations; checks and grades students' calculations and accuracy of the results; generates a grade report; and displays the grading scheme used.

When assigning essays or written reports as activities for grading, explain to students the important aspects of the assignments and describe how the activities will be graded. A grade might include content, research, references, reasoning, data analysis and clear expression. Another aid to student learning is to grade first drafts and give students a chance to resubmit an improved version. If instructor time is a significant deterrent to this approach, students can exchange draft reports with a partner or gather in a group and critique one another's drafts.

When assigning essays or written reports as activities for grading, explain to students the important aspects of the assignments and describe how the activities will be graded.

Oral reports and presentations can be difficult to grade, especially when students have little experience with public speaking. It can be hard to overlook poor delivery and focus on content. Some faculty members develop a scoring rubric that weight these two components unequally, and which gives credit for effective use of visuals. When students do more than one presentation in a term, the weight given to delivery is increased to reflect the expectation that they will improve with experience.

Group activities are difficult to grade on an individual basis. Most instructors find that a good way to grade a group is to make the entire group responsible for the answers, presentation, and results, by giving each group member the same grade. This encourages more skilled students to help their peers. Observing the groups in action will give you an idea of how each participant performs as a partner. Students are also quite cognizant of their contribution and their fellow classmates' contributions. One approach is to ask students to estimate the percentage of the final project that can be attributed to each group member, including themselves. You can use these ratings from all members to construct a participation score, so that there are slight differences when one group member contributes significantly more or less than the others. Some recommend that group activity grades account for only a small portion of a student's overall grade in the class (Johnson, Johnson & Smith, 1991).

You will need to decide how to address homework problems, if you feel that these are an important aspect of student learning. If you choose not to collect and grade them, many students will interpret that as a signal that you do not consider them important. However, some faculty members get around this problem by duplicating some of the assigned problems on their tests. If you choose to make homework a part of the final course grade, you need to make a number of decisions. What percentage of the overall grade should homework be? Will students work alone or in groups? Will they submit individual papers or a single answer set for the group?

Grading Writing[82]

The two most prominent ways of assessing student writing are analytic and holistic scoring. The analytic approach to grading considers writing to be made up of various features, such as creativity, grammar, succinct expression of concepts, and punctuation, each of which is to be scored separately. An analytic writing score is made up of a sum of the separate scores and is often a weighted sum developed after multiplying each score by numbers representing the relative importance of the features the instructor wishes to emphasize. Holistic scores are arrived at by comparing individual student essays to model essays representing good, fair, and poor responses to the assignment.

A third variation is a type of global scoring which assumes that writing is the sum of various features but assigns the final score without the use of a scale. This method, which is most frequently used in casual approaches to grading writing, tends to result in less precise assessment.

Analytic Scoring

Analytic scoring is the traditional approach to grading writing. Instructors who use analytic scoring view writing as a demonstration of many isolated skills that when graded separately and added together will come up with an appropriate assessment of the piece. Many instructors choose to use analytic scoring because of its strengths, some of which are as follows:

- It helps instructors keep the full range of writing features in mind as they score. An essay that is poorly punctuated may present a good analysis of a problem and/or strongly state a position. The punctuation may overwhelm the instructor to the degree that he or she fails to notice the strong elements of the essay and grades it too low.
- It allows students to see areas in their own essays that need work when accompanied by written comments and a breakdown of the final score. Its diagnostic nature provides students with a road map for improvement.

Some weaknesses of analytic scoring are:

- It is time-consuming. Teachers who score analytically usually are required to make as many as 11 separate judgments about one piece of writing. Furthermore, not all students actually make their way through the analytic comments so painstakingly written on their papers, nor will all be able to make profitable use of those comments on succeeding writing assignments.

- Negative feedback can be pedagogically destructive. Teachers who combine analytic scoring with confrontational or unclear comments – especially about issues of grammar – may actually inhibit student growth.

The following guidelines may be useful to maximize the effectiveness of analytic scoring:

- A written analytic scale helps to define grading criteria clearly and, if shared with students, can foster an understanding of what is expected and how it will be assessed.
- Criteria are weighted according to their relative importance. For instance, if the goal of an assignment is the assimilation of course material, then logic, ideas, arrangement, and resourcefulness are rewarded more than grammar and mechanics.
- Formative feedback in the form of marginal and end comments is most effective when the comments are balanced and both challenge and support students. Good writing is tough to do, and most students feel inadequate about their writing skills from lack of practice.
- Instructors can downplay the possible confrontational effect of grading by being sensitive to such issues as using sarcasm in their comments, obliterating students' work with lines, and the like.

Holistic Scoring

Writing experts have developed a special process for grading called holistic grading, which is especially useful in grading large numbers of essays. Student essays are usually graded by more than one person. Using assessment criteria developed from the learning objectives for a writing assignment, an instructor selects several student essays that exhibit high, average, or low achievement. These models then become the standards by which the instructor and one or more graders assess a group of essays. Each person reads the student paper quickly and determines whether it is stronger or weaker than its closest equivalent among model essays. As with analytic scoring, it is important that students are made aware of the method of assessment and criteria in advance of their writing.

Holistic scoring has two advantages over other scoring methods:

- Reliability. Holistic scoring is considered by some to be the most consistent and reliable method of scoring writing available to date.
- Efficiency. Holistic scoring takes much less time to do. Each reader of a holistically scored essay reads the essay through quickly, matching its quality to that one of the model essays. With the models firmly in mind, a holistic grader's first impressions of an essay are highly reliable.

Holistic scoring has the following disadvantages:

- While the score given will be reliable, the student will not necessarily know the reason for his or her grade on the writing. Most instructors go back and make some kind of end comment on holistically scored essays to give the student some idea of why the essay was better or worse than the model essays. Formative comments with regard to specific areas in need of improvement are not available to the student. Model essays can be given to the students for comparison.
- Holistic grading can be impractical for individual instructors. While an individual instructor could go through a stack of papers looking for high, middle, and low models and grade the rest of the papers according to these models, the best situation for holistic grading occurs when two or more instructors work together. Holistic grading is ideal for large enrollment courses in which two or more TAs are responsible for the grading.

Summary of Assessing Student Performance

Tailor your grading approach to your goals for the course.

- ☑ Be sensitive to non-English speakers' needs in your courses.
- ☑ Incorporate assignments relating to students' backgrounds and interests.
- ☑ Test for your students' knowledge, application, analysis, comprehension, synthesis, and evaluation abilities.
- ☑ Do not write overly difficult test questions. Allow students five times as much time to solve a problem as you would require.
- ☑ Use a grading matrix or rubric for uniform and fair assessment of student work.
- ☑ Provide informative, specific feedback on assignments and exams.
- ☑ Give students frequent, specific feedback in performance settings such as lab courses.
- ☑ When grading writing, consider the advantages of analytic versus holistic scoring methods.

How to Evaluate Your Own Teaching

Evaluating Your Own Teaching[83]

A Definition of "Evaluation"

Doing good evaluation is like doing good research. In both cases, you are trying to answer some questions about an important topic. The key to doing both activities well is (a) identifying the right questions to ask and (b) figuring out how to answer them.

Five Sources of Information

There are five basic sources of information that teachers can use to evaluate their teaching. All evaluation efforts use one or more of these basic sources. Each of these five sources has a unique value as well as an inherent limitation.

1. Self-monitoring

Self-monitoring is what people do semi-automatically and semi-consciously whenever they teach.

- *Special Value*
  The first value of self-monitoring is that it is immediate and constant. You do not have to wait a week or a day or even an hour to get the results. Hence, adjustments are possible right away.

  The second value is that this information is automatically created in terms that are meaningful to the teacher because it is the teacher who creates the information.

- *Frequency*
  This does and should happen all the time. We may only take a mental pause every few minutes to size up the situation. But by comparison with the other sources of information discussed below, this takes place continuously.

- *Limitation*
  The very strength of this source is also its weakness. Because this information is created by us for us, it is also subject to our own biases and misinterpretations. This means that, at times, we are going to misread the responses of students to our teaching.

2. Audiotape and Videotape Recordings

Modern technology has given us relatively inexpensive and easy access to audio and video recordings of what we do as teachers.

- *Special Value*

  The value of audio and video is that it gives us totally objective information. It tells us exactly what we really said, what we really did, not what we thought we said or did. How much time did I spend on this topic? How many times did I ask questions? How often did I move around? These are questions the audio and video recordings can answer with complete accuracy and objectivity.

- *Frequency*

  Video recordings are probably useful once every year or two. As we grow older, we change, and we need to know what we look like to others.

- *Limitation*

  What could be more valuable than the objective truth of audio and video recordings? Unfortunately the unavoidable problem with this information is that it is true but meaningless – by itself. The recordings can tell me if I spoke at the rate of 20 words or 60 words per minute, but they can't tell me whether that was too slow or too fast for the students.

3. Information from Students

As the intended beneficiaries of all teaching, students are in a unique position to help their teachers in the evaluation process.

- *Special Value*

  If we want to know whether students find our explanations of a topic clear, or whether students find our teaching exciting or dull, who else could possibly answer these kinds of questions better than the students themselves? Of the five sources of information described here, students are the best source for understanding the immediate effects of our teaching (i.e., the process of teaching and learning.)

This information can be obtained in two distinct ways: questionnaires and interviews. Each method has its own relative value.

3A. Questionnaires

The most common method of obtaining student reactions to our teaching is to use a questionnaire.

- *Special Value*

  The special value of questionnaires, compared to interviews, is that they obtain responses from the whole class and they allow for an anonymous (and therefore probably more candid) response.

- *Frequency*

Questionnaires should be given at three different times: the beginning, middle and end of a course. Use questionnaires at the beginning of a course to get information about the students, e.g., prior course work or experience with the subject, preferred modes of teaching and learning, and special problems a student might have (such as dyslexia). Use mid-term questionnaires to get an early warning of any existing problems so that changes can be made in time to benefit the students. The advantage of end-of-term questionnaires is that all the learning activities have been completed. Consequently, students can respond meaningfully to questions about the overall effectiveness of the course.

- *Limitation*

The limitation of questionnaires is that they can only ask a question once, i.e., that cannot probe for further clarification, and they can only ask questions that the writer anticipates as possibly important.

3B. Interviews

The other well-established way of finding out about students' reactions is to talk to the class. Either the teacher (if sufficient trust and rapport exist) or an outside person (if more anonymity and objectivity are desired) can talk with students for 15-30 minutes about the course and the teacher.

- *Special Value*

The special value of interviews is that students often identify unanticipated strengths and weaknesses, and the interviewer can probe and follow-up on topics that need clarification.

- *Frequency*

I would probably only use a formal interview once or at most twice during a term. Of course, a teacher can informally visit with students about the course many times, and directly or indirectly obtain a sense of their reaction to the course.

- *Limitation*

Although students know better than anyone else what their own reactions are, they can also be biased and limited in their own perspectives. They occasionally have negative feelings, often unconsciously, about women, people who are ethnically different from themselves, and international teachers. Perhaps more significantly, students usually do not have a full understanding of how a course might be taught, either in terms of pedagogy or content.

4. Students' Test Results

Teachers almost always give students some form of graded exercise, whether it is an in-class test or an out-of-class project. Usually, though, the intent of the test is to assess the quality of student learning. We can also use this information to assess the quality of our teaching.

- *Special Value*
  The reason for teaching is to help someone else learn. Assuming we can devise a test or graded exercise that effectively measures whether or not students are learning what we want them to learn, the test results basically tell us whether or not we are succeeding in our whole teaching effort.

- *Frequency*
  How often should we give tests? Many teachers follow the tradition of two midterms and a final. In my view, this is inadequate feedback, both for the students and for the teacher. Weekly or even daily feedback is much more effective in letting students and the teacher know whether they are learning what they need to learn as the course goes along. If the teacher's goal is to help the students learn, this is important information for both parties. And remember, not all tests need to be graded and recorded!

- *Limitation*
  It might be hard to imagine that this information has a limitation. After all, this is what it's all about, right? Did they learn it or not?

  The problem with this information is its lack of a causal connection.

5. Outside Observer

In addition to the perspectives of the two parties directly involved in a course, the teacher and the students, a third party's observations can provide valuable information. Such an observer can bring both an outsider's perspective and professional expertise to the task. A variety of kinds of observers exist: a peer colleague, a senior colleague, or an instructional specialist. It can also be highly valuable for new instructors to connect with a teaching mentor.

- *Special Value*
  Part of the value of an outside observer is that they do not have a personal stake in the particular course; hence, they are free to reach positive and negative conclusions without any cost to themselves. Also, as a professional, they can bring an expertise either in content and/or in pedagogy that is likely to supplement that of both the teacher and the students.

- *Frequency*

  Beginning TAs and beginning faculty members should consider inviting one or more outside observers to their classes at least once a semester for two or three years. They need to get as many new perspectives on teaching as soon as possible. After that, more experienced teachers would probably benefit from such feedback at least once every year or two. We change as teachers; as we do, we need all the feedback and fresh ideas we can find.

- *Limitation*

  Again, the strength of being an outsider is also its weakness. Outside observers can usually only visit one or two class sessions and therefore do not know what happens in the rest of the course.

  Apart from this general problem, each kind of observer has its own limitation. The peer colleague may also have limited experience and perspectives; the senior colleague may be someone who makes departmental decisions about annual evaluations and tenure; and the instructional consultant may have limited knowledge of the subject matter.

A Note on Teaching-as-Research

Teaching-as-research is an exciting way to hone your classroom skills. This section has only presented a limited introduction to the process, providing a starting point for you in developing inclusive and well-designed courses. We encourage you to seek out materials that are relevant to your work. We recommend the following scholarly sources related to teaching-as-research:

Fink, L. D. (2003). *Creating significant learning experiences: An integrated approach to designing college courses*. San Francisco, CA: Jossey-Bass.

Huba, M. E., & Freed, J. E. (2000). *Learner-centered assessment on college campuses : shifting the focus from teaching to learning*. Boston, MA: Allyn and Bacon.

Maki, P. L. (2004) *Assessing for learning: Building a sustainable commitment across the institution*. Sterling, VA: Stylus Publishing.

Walvoord, B. E., Johnson, V. J., & Angelo, T. A. (1998). *Effective grading: A tool for learning and assessment*. San Francisco, CA: Jossey-Bass.

Wiggins, G., & McTighe, J. (1998). *Understanding by design*. Alexandria, VA: Association for Supervision and Curriculum Development.

Part Four:
Appendices

Part Four: Appendices

The resources included in this book are only the beginning of what is available. We have developed several lists of materials for faculty and future faculty. We hope that you will consult these references for specific information about ways to create positive, dynamic, and inclusive classroom environments.

The appendices are divided into four sections:

1. Essays on solutions to challenging teaching issues and reflections on teaching by experienced faculty and award-winning graduate students
2. A list of additional resources
3. Useful Web sites that have been evaluated by our colleagues and staff
4. Suggested material for development of graduate assistant handbooks

Appendix 1: Inspirational Essays

Mathematics: The Universal Language of Science[84]

In the fall of 2001, when I was assigned to be a graduate student instructor for Statistics 205A for the second time, I was determined to change my teaching style. Statistics 205A is an introductory graduate-level course on classical probability theory. In recent years, however, students from a wide variety of fields have taken the course. Besides having statistics and probability students in my class, I had students from electrical, mechanical and civil engineering, operational research, economics, computer science and sociology. It was a challenge to make such a diverse group of students realize that the study of probability theory would be useful to them in their fields. This was particularly difficult because the course did not have any discussion hours. To handle the problem, I realized that I needed to have some discussion hours where I could meet with the students regularly.

The professor teaching the class was very supportive of my idea, and the students also responded positively to the suggestion, so I started holding three hours of discussion every week. My job was to motivate the students and help them understand the difficult and involved concepts of classical probability, so I decided to treat the discussion hours as though they were language study sessions. The most important part was to make the students realize that what they were learning was not just abstract nonsense but part of a universal language, which would give them the necessary skills to "communicate" regardless of their different academic backgrounds.

In each session, I led the discussion by pointing out various important interpretations and applications of some mathematical concepts or problems. This automatically elicited spontaneous responses from the students, which almost always ended in a debate in the language of mathematics. This way, they not only started "talking" in mathematics but, while doing so, they also started appreciating the need of this rather precise language. In addition, I gave them language drills to give them confidence in the skills that they were developing through this exercise. Many times, I asked sudden questions or gave them quizzes, which they had to discuss among themselves and then answer. This also helped them to commit the fundamental ideas to long-term memory.

It was quite apparent from the great enthusiasm and student participation in the discussions that this new teaching style was effective and helpful. I also found from individual meetings with students during office hours that they were happy with the new learning experience. The final confirmation of the success of my teaching came at the end of the semester through the course evaluations. I was pleased to receive lots of positive comments from the students and not a single complaint. But the best reward I received from teaching Statistics 205A came a couple of months ago, when I ran into a student from my class who told me that she would definitely take another course on probability theory if I were teaching one.

Transforming Quizzes into Teaching and Learning Tools[85]

The semester I was a graduate student instructor for Survey of Genetics, the professors decided that the students would be given a short quiz every other week in their discussion section. The students' grades on the quizzes were to be based solely on attendance: if a student came to section that day and turned in a quiz, she or he would get full credit for the quiz. While the professors' intent to encourage students to attend discussion section was good, I wanted the quizzes to be more than just an attendance incentive. I expected that many students would not feel compelled to study for the numerous quizzes if their grades did not depend on them, thus diminishing the possibility of using the quizzes to assess students' progress in the course. In addition, I suspected that many students would not take the time to examine their corrected quizzes closely, thereby missing the opportunity to identify gaps in their knowledge before the exam. To address this problem, I developed a quiz strategy for my discussion section that was consistent with the course guidelines set by the professors, but would still encourage the students to take the quizzes seriously so that the grades would allow me to evaluate their progress in the course.

My strategy involved correcting the quizzes together in class immediately after the students finished the quiz instead of grading them myself. Rather than just telling the students the answers, I asked volunteers to come up to the chalkboard and write their answers for the rest of the class. Students were allowed to ask for help from classmates if necessary. On particularly tricky questions, I had two students work together at the board so they would feel less intimidated. Taking turns putting their quiz solutions on the board encouraged them to study for the quiz, since they knew they would have to get up in front of their peers. Also, they were able to identify gaps in their knowledge of the course material by correcting the quizzes themselves right after taking them. At the end of class, I collected the quizzes so that I could determine which topics were particularly difficult for the class as a whole and spend more time reviewing them with the students. I then returned the quizzes in the following section so the students could use them as study guides.

The effectiveness of this interactive method was confirmed by feedback from the students. As a formal evaluation, I requested that the students fill out anonymous midterm evaluations of the course and discussion section, in which I asked them specifically about the grading format of the quizzes. The students stated their overwhelming support for the method. Several students said it greatly helped them prepare for the exam, and admitted that otherwise they probably would not have studied for the quiz and would have recycled their papers without going over the corrections. In addition to positive written support from the students, I noticed a huge increase in class participation relative to the days where there were no quizzes. As the semester progressed, the students were more confident about asking and answering questions. In comparing notes with other TAs for the course, it also seemed that my students were more willing to ask questions in section and took their quizzes more seriously than students in other sections did.

The students benefited from this method because they had a strong incentive to study for the quizzes, and in so doing so, learned the course material in smaller sections rather than waiting to cram for the exam. They also received immediate feedback on their progress by going over their answers in class after the quiz. I collected the quizzes after the students graded them so I could notice if there were any difficult topics that I needed to spend more time reviewing. Increased class participation also made discussion sections more productive and enjoyable for both me and the students. Finally, the method was consistent with the professors' guidelines, since the actual numerical quiz grade was based solely on attendance.

Teaching My Students to Fish[86]

Give a man a fish and he will eat for a day. Teach a man to fish and he will eat for a lifetime. I have found this old Chinese proverb as applicable to filling a student's mind with knowledge as it is to filling an empty stomach with food.

During my tenure as a graduate student instructor for the Department of Mechanical Engineering, I have regularly encountered students who, in the context of the Chinese proverb, seek handouts of fish: they would rather be given the answers and solutions to their assignments than have to work to find them. They would gladly take whatever shortcuts there may be to obtain a good letter grade. Although such cases may be less common in other academic departments, many engineering students have been conditioned to think that they can succeed by simply duplicating textbook examples or blindly using mathematical formulas without understanding the underlying theory. Teaching these students to engage in critical thinking is vital, and was a particular challenge in the course I taught, ME 107A: Experimentation and Measurement.

In ME 107A, students performed experiments related to a variety of engineering topics such as acoustics and fluid mechanics. They were given lectures and handouts to provide theoretical background as well as to describe experimental equipment and procedures. This information was meant to guide the students in their laboratory assignments, not to provide them with step-by-step instructions on carrying them out. However, as the instructor, I was often asked during lab to provide explicit direction. Students would ask me questions such as, "Where am I supposed to plug this cable?" or, "How many data points am I supposed to take?" When attempting to run a data acquisition program that was provided to them, they would find me and say, "My program doesn't work," with the implicit follow-up question, "Could you fix it for me?" These situations would occur before the students had thought about the problems they were faced with or attempted to resolve the problems for themselves.

The first step I took to encourage students to think more carefully about their lab assignments was to refrain from simply answering the questions I felt they were capable of answering themselves. I would ask them to tell me what they were trying to accomplish in their experiment and lead them to the answer rather than give it to them. I would remind them what the objective of the experiment was and ask them what data they felt they would need to obtain that objective. For the data acquisition software, I implemented a specific change to promote better understanding of the software and its use in the lab. Rather than give the students a program to copy onto their lab computers, I made it part of the assignment to develop the program, requiring them to understand the role it played in collecting and processing the experimental data as well as the manner in which it controlled some of the hardware.

Although some students were initially frustrated by my refusal to simply tell them what to do, I believe that they came to understand the value of thinking analytically about the experiments they were conducting and the assignments they were given. One student even went through a short period of time in which he would start to ask a question but then retract it, realizing that I would want him to think about it more carefully before seeking my help. After observing such changes in the students and receiving positive feedback at the end of the course, I noticed that my efforts had not been in vain. Much like teaching the man in the Chinese proverb to fish, I felt that teaching my students the way to think about and analyze engineering problems provided them with a valuable skill, which they hopefully can further refine and use as their careers progress.

Chemistry: The Other Foreign Language[87]

How is it that a student can come to my office hours, explain the complicated concepts that a problem set question is based on, and even go as far as to intuit the right approach for solving the problem, yet not be able to derive the right answer?

I am sure many TAs in general chemistry, or of any introductory physical science class, have asked themselves this question numerous times throughout a semester. One of the biggest problems facing students in general chemistry classes is their inability to communicate what they actually know about the concepts on an exam or a problem set.

Being unable to communicate what they know, and receiving low test scores on material they actually understand, will undoubtedly frustrate students to the point of giving up. The reason for the students' lack of chemical communication skills is simple: they spend very little time learning, practicing and speaking the language of chemistry. The problem is further worsened when TAs use discussion sections as just another lecture session or review session, and spend the majority of time talking to the students instead of having the students do the majority of the talking.

My solution to this problem was to treat the discussion section as though it was a foreign language drill section. The most important task in discussion was to make the students practice communicating what they had already learned. In chemistry, students must communicate through problem solving. Therefore, I began each discussion by instructing the students to work individually on example problems that were representative of the material and concepts covered in lecture that week. Then, they would break into groups to discuss their approach and answers. Finally, I would send a student from each group to the board to communicate their approach to the problem. The students at the board were expected to defend their approach and answer questions raised by other students. During this process, I would remain very quiet, interjecting a comment only when the students were at a standstill or off on a tangent.

After the problem solving session, I would lead the students in language drills. Because problem solving requires a vocabulary of the necessary equations and conceptual approaches, I would drill the students on the equations and concepts discussed in lecture that week. My drills were in the form of quiz-show games, relay races, and student vs. student competitions: anything to avoid the inherent boredom that comes with performing rote tasks. The repeated, rapid-fire practice with the equations and concepts helped the students become more fluent with the material, and therefore more easily commit the information to long-term rather than short-term memory.

I believe my approach to these discussion sections was successful based primarily on student reviews as well as the students' progress on quizzes and exams throughout the semester. I regularly asked the students as a group and individually whether they found the discussion section helpful. Two times during the semester, I asked the students to review, confidentially, the discussion section and to give advice on what I should and shouldn't continue. An overwhelming number of students responded that the problem solving sessions and drills were very helpful, and wanted more time devoted to those exercises. Furthermore, my section as a whole improved continually on exams throughout the semester. The section went from being one of the lower scoring sections (below the class mean) on the first exam to being the highest scoring section on the final exam by an entire standard deviation.

Teaching to Different Modes of Learning[88]

In the fall of 1999, I taught an upper division course in animal behavior in which one of my students was blind. Up until this point I had little experience working with students with disabilities, and had never before taught a visually impaired student. Most courses in biology are visually extensive, relying on numerous charts, figures, and diagrams to illustrate important concepts, and the course on animal behavior was no exception. Much of the information presented in lecture was in the form of pictures and graphs, and almost every assigned reading included additional figures and charts that either contained data or diagrammed processes. Such emphasis on visual learning presented an obvious obstacle to my student.

It was clear early on that my female student with a visual impairment was having a difficult time understanding the course information, as her lecture notes were based only on what the professor or I had said, and completely lacked anything that was presented on the chalkboard or on overheads. Furthermore, most of the reading and homework assignments required analysis of figures and graphs from various articles and, without being able to view the diagrams, she was clearly unable to perform this task sufficiently. When the issue first arose a few weeks into the semester, she was understandably frustrated with the course, and her performance in it was low.

In order to overcome this learning obstacle, we decided that I would meet with her privately, outside of my regular office hours, approximately once a week, to go over lecture material. Additionally, I agreed to verbally review the reading and homework assignments with her, guiding her in completing the assignments without giving the answers away. I admit that, without the use of diagrams or figures, I initially struggled in our weekly meetings to explain clearly the important information and concepts that were being presented in the lectures. I was personally amazed at how much emphasis was (and still is) placed on visual aids in learning about biology, and it was obvious that she was surprised as well – she admitted that she had taken few courses which had depended so heavily on diagrams and pictures.

This course posed a challenge for both of us: for me, on the teaching end, and for her, on the learning end. Even so, we stuck to it, and what transpired over the next few weeks was a rigorous effort on my part to mold my teaching of biology into a form that she was easily able to access. This consisted primarily of explaining in words not only what a figure looked like but what important information it was trying to convey. Often, this was best achieved by first explaining what the figure looked like in concrete terms, and then discussing the same information in a new way that did not rely on the figure. This follow-up aspect required me to be creative, using metaphors or real examples from her life that could be compared to the biological concept at hand. On more than one occasion, I even attempted to use a physical learning technique by having her touch or feel things in the room in a particular way or pattern in order to relay a general idea or theory that was implicit in the biology being taught.

We had to work at it, but by the end of the third week, our personal meetings had evolved to be stimulating, creative, and most importantly, effective in teaching her biology. This was confirmed by a steady increase in her overall performance on course assignments and exams, and just as importantly, an increase in her enthusiasm and interest in the course itself. In fact, in our first weekly meeting she had discussed the possibility of dropping the course, but as the weeks passed this idea disappeared, and she eventually went on to finish the course.

This is one example of how I was able to help a student with a specific learning need. More importantly, however, my teaching as a whole benefited from this process. As the semester progressed, a larger and more general issue became clear to me: different students learn in different ways. This idea applies not just to students with learning disabilities, but to all students. Some students are visual learners, requiring pictures and diagrams to process and understand information. Other students are auditory learners, learning best through listening, word-for-word note-taking, and a focus on memorizing definitions and categorizing facts. Additionally, there are many students who learn best through examples and active participation.

Just as there are many things that are best learned through practice or through direct observation, there are many students who learn processes and concepts most effectively by observing them in real life or, if possible, by actively participating in them. Realizing that different people learn in different ways, I believe, vastly improved my teaching, not only for my blind student but for all my students. Throughout the remainder of the semester, I attempted to always explain things in more than one way, constantly accessing multiple modes of learning. Thus, every time I drew a diagram, I also verbally explained what I was drawing and why I was drawing it in that way. Furthermore, I would then follow this up by creating a scenario or metaphor outside of science that students could personally relate to, and that illustrated the same underlying principles of the course material.

Presenting the same information in different ways, I believe, allows for better teaching because it allows students with diverse learning abilities to access and understand what you are trying to teach. Based on the performance of my students in the classroom and on graded assignments, I believe that my teaching has continued to improve and become more effective, whether it be in one-on-one situations, as with my blind student, or in a large classroom setting. I plan to continue to apply the valuable information I gained from this experience to my future teaching.

Note: new technologies such as thermoforming can be used to generate three-dimensional representations of images for blind students.

Notes from a Career in Teaching[89]

I taught my first college class in 1964, at College of the Holy Names, now Holy Names University, in Oakland, CA. I knew almost nothing about teaching, did a lousy job, and was not rehired for the next semester. My last teaching position was at Indiana University at Bloomington in 2004. After the spring semester, I retired as a professor amid much praise from students, colleagues, and teaching professionals.

Over those four decades, my teaching had clearly improved. What, specifically, had I learned? Here are some lessons that I’d like to share in hopes other college instructors might benefit from some or all of them.

Teach according to your personality.

Most students possess superb radar that quickly locates phoniness in professors. Thus, every teacher has to figure out who she or he is, how best to appear before a class, and what material to teach. And, in long teaching careers, every instructor should have three-to five-year checkups and revise their dress, approach, and material as their personal values and circumstances change. Teaching is a highly individual endeavor, and each instructor should work according to what personally feels most comfortable. I went to graduate school at the University of California-Berkeley in the 1960s, and came out of that era and ethos believing that instructors should befriend students and dress like them. So I wore jeans, T-shirts, and sneakers. But most students were not very friendly, and my classes seemed to move at a slow, sometimes painful pace.

One day at Indiana University in the early 1970s, I was assigned to observe the class of a young teaching assistant. He met me at the classroom door dressed in a three-piece suit, tie, and polished dress shoes. I assumed that he could not relate to the students and that I would endure a long and tedious hour.

He asked the students to move the chairs from the discussion circle in which they rested to straight rows from front to back. I considered that a mistake, like his formal attire and stance in front of the class. But as he talked, with very proper diction, his excitement about the material became increasingly apparent. I looked around and saw that students were paying close attention and taking notes. When he paused and requested questions, many hands went up. The students asked good questions, he responded well, and then returned to his lecture. That format continued for about 20 minutes, after which he summarized his talk and told the students to write answers to some questions that he handed out.

As part of my job as observer, I asked the instructor, with about 15 minutes remaining in the period, to leave the room so I could discuss his teaching with the students. As soon as he left, the students spontaneously began to praise him. I was skeptical: “Wasn't he too formal? Do you really relate to someone like that in a three-piece suit?” But indeed they did – even though most of the men wore torn T-shirts and the women had on tie-dyed outfits. They truly liked and respected his enthusiasm for the material.

That experience overturned many of my prejudices about teaching. I decided to teach more in line with my personality. Although I wasn’t a suit-and-tie person, I wasn’t as laid back as my appearance implied. I felt most comfortable in front of a class in pressed slacks, collared shirts, and loafers. I also tried to teach material that I cared about deeply rather than literary works that the English department recommended. (Fortunately, my boss encouraged my excursions.)

My classes became livelier, and my student evaluations improved greatly. I had learned a crucial lesson.

Hand out complete syllabi and course instructions the first day.

From my Berkeley background in the 1960s, I also did not believe in elaborate syllabi and course instructions. Instead, during the first classes in a course, the students and I would agree on what we would do and how we would do it. Yet I came to see that such an approach resulted in much confusion among students and wasted time for me answering logistical questions like, "What's the policy on late papers?" I realized that the ideal was interfering with learning.

Over the years, my initial handouts increased in size but also provided a reference guide to all aspects of the course. During my last decade of teaching, I noticed that many students wrote on course evaluations comments like, "I always knew what was going on and what I had to do." I took that as a compliment – and a reinforcement that I'd been right to abandon my original approach.

Vary your teaching methods. Nothing bores students – and teachers – as quickly as relentless lecturing. A close second is relentless, yet aimless, class discussions. After much trial and error in my early years of teaching (my errors and the students' trials), I concluded that mini-lectures coupled with focused discussions worked best for me. In the process, however, I found that one of my key challenges was encouraging class participation.

Calling upon people with their hands raised usually produced comments from the same five or six highly verbal or chatterbox students and frequent hostility from the taciturn majority. But randomly calling on students did not work well either; some students felt that I was "picking on" them.

I decided one day to have every student bring a question on the reading assignment to the next class, but that produced many questions scribbled quickly, and without much thought, immediately before the class began. I then modified the format and asked students to write single-paragraph answers to their questions. That approach produced much better questions as well as coherent answers.

I then tweaked the format and asked students to make two copies of their questions and answers and to hand in one before class. I then ordered what they'd given me according to topics and used that order to guide classroom interactions. I asked each student not to give her or his answer until the class had discussed the question. On occasion, I also assembled students in groups of five or six to ask other members of the group their questions, or to make up new questions and answers and then ask the class.

The surprise element of the "Q-and-A papers" was that some students, particularly shy or reticent ones, participated in class discussion despite their inclination not to, and they seemed to enjoy the experience. I recall one young woman telling me at the end of a course, "I'm graduating this semester, and I talked more in this class than all my other classes at Indiana combined. Thank you."

Don't take attendance.

I've always assumed that universities are not high schools and that college students are adults, attending class as their choice. In my course handout, I wrote: "If you choose to use the time of the class meeting to do something else, that is your decision... You are responsible, however, for understanding the material done in class during your absence, and I will grade your work in the course under the assumption that you have mastered that material. However, if you miss class because of illness, I will help you make up the work."

An equally important reason for my policy was that otherwise I'd have to deal with many students who, having no desire to be in the room, would shuffle papers, pop gum, snore loudly, and engage in other distracting behaviors. They changed the ambience of the classroom, and I decided that I much preferred to teach a smaller number of volunteers than a large army of conscripts.

In addition, not requiring attendance allowed students to vote with their feet on my teaching. If attendance dwindled, I realized that I needed to rethink the section of the course where students did not come – or, on several occasions, the whole course. But if they showed up in large numbers, I knew that I was doing a good job.

Take a hard line on late and incomplete work. I always believed that turning in late work or receiving an "Incomplete" grade are special privileges that should be reserved for extraordinary occasions – when students had serious physical or psychological problems. I also required any student in that situation to have a signed letter from his or her doctor, stipulating the nature of the student's illness and when the physician thought the student would be well enough to finish the work.

I took a letter grade off for late work – including missed quizzes, exams, and Q-and-A assignments – without a medical excuse. I know the policy seemed punitive to some students, but I had to be fair to other class members who turned in their work when it was due.

Ironically, the people who complained most about the policy were not my students, but a number of my colleagues. They said that some of their students were asking them for "extensions" and even "Incompletes" in courses so that they could get their work for me in on time. I suggested to my colleagues that they switch to my policy.

Give students lots of options for major assignments and exams.

During my early years of teaching, I realized that the best student work came out of a student's real interests. If I assigned a narrow essay on a specific topic, a few class members wrote it exceptionally well, others earned good grades on it, but many students did indifferent or poor work. If, instead, I encouraged students to identify their own topics connected to the course and to pursue them with my help, many more students wrote good papers. My assignments remained analytic approaches to the subject matter, however, and one group of students still underachieved on papers and exams – even though they had demonstrated in class and office discussions that they thoroughly understood the material.

At the time, in the 1970s, the research on left-brain and right-brain dominance became public knowledge. I decided to allow students to substitute some creative papers and take-home exams for analytic ones. For example, when we read John Dos Passos' *U.S.A.* in a course, students could write a creative paper – equal in length and difficulty to the analytic ones – using one of Dos Passos' techniques, like a biographical portrait of an historical figure in the style of Dos Passos, or a "Camera Eye" personal commentary on an American scene of the period. Or students could suggest another type of creative paper or take-home exam connected to the material. While only about a fifth of the students took the creative option, most of the results were excellent and continued to be so in subsequent years. Moreover, I could reward the right-brain-dominant students with the grades that they deserved.

Get out of the way.

The best teaching occurs when students take something that the instructor has set up and then develop it on their own. Sometimes that occurs in class discussion when students seize a topic that the instructor mentions and start to argue about it in a focused and productive manner. The instructor is often tempted to jump in, but the best thing is to shut up and get out of the way.

It took me many years to realize that less can be more in teaching – that, in the end, the instructor must disappear from the learning process, and students must learn on their own. I don't know why it took me so long to realize that simple truth; as an undergraduate and even as a graduate student, I mainly learned on my own. Indeed, I came to believe that the main point of course work was to direct me to the library and show me how to use what I found there.

The single best course I taught in 40 years was the last one: an undergraduate class on Beat Generation writers. I finally understood that my job was to set up interesting classes in ways that encouraged students to explore the subject matter. Almost every student rose to the challenge: they built upon the assigned works that we discussed and then went off and studied the writers and topics that most interested them.

One student discovered that the papers of the Beat poet Diane DiPrima were in the University of Louisville library, and she traveled there to examine them. She subsequently used photocopies of some of DiPrima's drafts as illustrations for her class presentation on this writer. Many other students ended up doing superb major projects and take-home final exams, and they earned high grades in the course.

So, my final and best piece of advice for good teaching is: construct interesting courses, with the logistics clear from the first day, and then get out of the way. If you have done your job, students will learn on their own – and that knowledge will stay with them long after they have left your classroom.

Appendix 2: Additional Resources

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Appendix 3: Web Sites

General Sites

U. of Minnesota Syllabus Tutorial:
http://www1.umn.edu/ohr/teachlearn/tutorials/syllabus/

North Carolina University:
http://labwrite.ncsu.edu/instructors/gradinglwr.htm

Gender and STEM education (@ the NSF):
http://www.nsf.gov/dir/index.jsp?org=EHR

National Center for Case Study Teaching in Science:
http://ublib.buffalo.edu/libraries/projects/cases/case.html

Interactive Learning Materials for Math (from Duke):
http://www.math.duke.edu/education/ccp
http://www.math.duke.edu/~das/essays/thinking

Fonts and Dyslexia:
http://www.dyslexic.com/fonts

Diversity in Higher Education Website:
http://www.diversityweb.org/

Conflict Resolution:
http://www.msu.edu/user/gradschl/all/crvideo.htm

Teaching and Learning Publications:
http://www.cetl.gatech.edu/resources/publications.htm
http://depts.washington.edu/cidrweb/inclusive/
http://teaching.berkeley.edu/bgd/teaching.html
http://dn.media.mit.edu/projects.html

AGEP web home:
http://ehrweb.aaas.org/mge/home.htm

Dennis Jacobs Carnegie project:
http://kml2.carnegiefoundation.org/gallery/djacobs/index2.htm
http://www.diversityweb.org/diversity_innovations/faculty_staff_development/recruitment_tenure_promotion/underrepresented.cfm

Women:

Women and Girls in Technology:
http://www.wgit.org/

Society of Women Engineers:
http://www.swe.org

Statistics about women in engineering in the U.S.:
http://www.swe.org/SWE/ProgDev/stat/stathome.html

Diversity in the Classroom: Links on the Web:
http://www.princeton.edu/~djbutler/ditclink.htm

UW-Oshkosh Women in Science website:
http://www.uwosh.edu/wis/

Retention of Minority Engineers website:
http://www.virtualpet.com/engineer/retent/retent.htm

Science and Engineering:

AAAS report on research base on diversity in science and engineering:
(see especially chapters on existing research and gaps)
http://ehrweb.aaas.org/mge/Reports/Report1/AGEP/AGEP_report.pdf

High school teaching - classroom level, from University of Illinois:
http://students.ed.uiuc.edu/freymuth/490i/diversityessay.htm

Teaching in Australia (see particularly pages 40-48 on modifying STEM culture, and classroom practices):
http://www.unisanet.unisa.edu.au/flc/staff/equity/documents/science.doc

NISE Field-Tested Learning Assessment Guide Site:
http://www.wcer.wisc.edu/archive/nise/

Engineering Department- or College-Specific Approaches:

South African example of using data to drive faculty behavior in an engineering department:
http://www.nae.edu/NAE/caseecomnew.nsf/weblinks/NFOY-5G8M78?OpenDocument

NSF funded report on fostering diversity in electrical and computer engineering:
http://www.ecedha.org/reports/AoC_Report.pdf

Institutional Approaches (generally focusing on faculty hiring):

University of Toronto - comprehensive approach:
http://www.provost.utoronto.ca/userfiles/HTML/nts_6_3430_1.html

University of Saskatchewan (see appendix 1):
http://www.usask.ca/diversity/report_summ.html

University of Nebraska – Lincoln:
http://www.unl.edu/pr/diversity.html

Assessment:

Classroom Assessment Techniques (CATs):
http://www.wcer.wisc.edu/archive/cl1/flag/default.asp

NISE Web Site:
http://www.wcer.wisc.edu/archive/nise/

Appendix 4: Graduate Assistant Handbook Outline

Here we provide recommendations for the type of institution-specific content that might be included with this book if it is used as a manual for graduate assistants. Every campus is different, so knowing about your department and institution is very important when trying to teach all your students effectively.

Department- and Institution-Specific Information

Graduate Assistantship Policies

- Fee Waivers/Scholarship/Tuition Remission
- Types of Graduate Assistantships
- Criteria for Awarding Graduate Assistantships
- Extent of Graduate Assistantship Support
- Application, Renewal, and Termination of Graduate Assistantship Support
- Graduate Assistantship Responsibilities and Compensation
- Performance Evaluations
- Rights of Teaching Assistants

Course Policies and Procedures

- Syllabi, Unit and Lesson Plans
- Sample Syllabus
- Class Rolls and Grade Books
- Course Packets and Readers
- Getting Feedback from Students
- Evaluating Teaching

Professional Policies and Procedures

- Time Management
- Defining Sexual Harassment
- Advising and Counseling

- Privacy of Student Records
- Letters of Recommendation
- Attire
- Departmental and Campus Student Demographics
- Accommodating Religious Holidays
- Campus Support on Issues of Diversity
- Other Resources on Diversity
- Assisting Students with Disabilities

Professional Ethics

- Academic Integrity
- Academic Misconduct
- Using Student Work Examples

18 Questions to Have Answered

The following are 18 questions that teaching assistants and new professors might need to be able to answer. A training manual should provide a list of campus services, policies, and where to locate information in order to answer questions like these.

1. What if a student comes to your office and starts talking about difficult personal problems s/he is facing?
2. What if a student wants to turn in an assignment late because the due date falls on a religious holiday?
3. What if a student wants to withdraw from the course two months into the term?
4. What if a name shows up on your final grade sheet for a student you have never met?
5. What if a student gives you a letter certifying that s/he has a learning disability?
6. What if a student with a broken leg is having a hard time getting to class?
7. What if a student turns in a paper that seems familiar - you think it's plagiarism, but you're not sure from where?
8. What if you witness two students cheating on an exam?
9. What if you get propositioned by a student, offering favors in exchange for a grade change?
10. What if you feel that you are being harassed by a student, a fellow TA, or a member of the faculty or staff? What if you see harassment between students?
11. What if you feel overwhelmed by your own life?
12. What if you disagree with something the faculty member has said in class?
13. What if grading is taking twice as long as you planned?
14. What if a student has clear difficulty with the mechanics of writing, more than you can address?
15. What if you want to recommend tutoring for a student?
16. What if an athlete or a musician requests a change in a due date because of a game/performance?
17. What if you realize that your students have little or no experience with research libraries and they need these skills for their papers?
18. What if you are sick and cannot teach?

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