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- to provide opportunities for professional growth and development of members of Maryland Community College faculty by the effective use of statewide resources;
- to foster and improve teaching excellence by promoting the sharing of ideas, instructional materials and strategies;
- to maximize the impact and effectiveness of available funds for professional development;
- to open new lines of communication between and among faculty members with similar disciplines and interests;
- to sponsor discipline and cross-discipline conferences;
- to promote the exchange of faculty among Maryland Community Colleges.

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DEMONSTRATION OF THE WIRELESS INTERWRITE SCHOOLPAD 400

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The following PowerPoint Presentation is a demonstration of the wireless Interwrite SchoolPad 400 and a discussion of its technical details, its features, its advantages, and challenges.

ENHANCING STUDENT INTEREST IN INTRODUCTORY ECONOMICS

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The introductory courses in the social or behavioral sciences are often considered boring and repulsive to typical college students. Nearly all such courses have a complex vocabulary that must be memorized to understand the subject. Economics is an even greater challenge for several reasons. First, the vocabulary has not only difficult definitions, but it then takes common words, such as "demand" and "supply" and gives them more complex meanings. Second, most economic concepts are abstract and have no "real world" dimension to which students can relate. Third, one vital method of explaining economic concepts and principles is by the utilization of graphs. Many students have had very little experience with plotting and reading graphs and they often find them confusing. Finally, there is a lack of connection to other subjects, even business subjects, for which economics is a prerequisite. These observations are not speculation on my part. After thirty years teaching, I often encounter former students who like to tell me that they "hated" economics when they were taking it, often referring to the problems mentioned above. Yet they also tell me that everything we covered in the course has been useful to them in later life.

What is needed are ways that make introductory economics more interesting and less abstract. Not only would it make learning economics more attractive to the students, but it would also mean that economics teachers would have more interesting classes and, not to be ignored, better student evaluations.

I would like to share with you several methods that I have found helpful in overcoming these adverse student reactions to economics. These methods actually make teaching the subject a greater pleasure for both the teacher and the student. Three methods that have proved effective are (1) using history to present economic ideas, (2) writing assignments that connect with the student's "real world," and (3) the connection between economic progress and cultural changes such as popular music and fashions. Since the application of these methods is quite different for introductory macroeconomics and microeconomics, I will first explain my applications of these methods to macroeconomics and then to microeconomics.

Macroeconomics is the study of the whole economy, including problems such as unemployment, inflation, and business cycles. Macroeconomic theory began with the Great Depression of the 1930's and the ideas of the British economist, John Maynard Keynes. Keynes theory was put into practice by the policies of President Franklin Roosevelt, but in a limited way. The many New Deal programs involved limited spending. The economy did not recover completely until the massive spending of World War II. I introduce the course by explaining the connection between economic theory and political policy, and then review national economic policy beginning with the supply-side policies of Abraham Lincoln. I then explain the inflationary monetary policies proposed by presidential candidate William Jennings Bryan, the Monetary Commission of 1905 created by Theodore Roosevelt to examine the need for a central bank, and the Federal Reserve Act of 1913 introduced by Woodrow Wilson. There was an explosion of new policies under FDR. This was a major change because it involved a greater government involvement in the economy. Students find this very interesting and ask many questions about historical and current policies. Later in the course I pick up this historical thread with the fiscal policies of Presidents Kennedy and Reagan.

A method of adding variety to the theoretical presentation is to show documentary videos about the Great Depression. These videos include reference to the prosperity of the 1920's and the impact of electricity, automobiles, telephones, motion pictures, and air transportation. This provides me with an opportunity to explain that the cause of the downturn in 1929 was general over-production and general unemployment. These were two things that classical economic theory said could not happen as long as prices, wages, and interest rates were flexible. Keynes explained that this indeed could happen and that government intervention with fiscal policy was the best solution. The appropriate fiscal policy would be to either lower taxes or increase government spending. My videos show mass unemployment, soup lines, rural poverty, the Dust Bowl in the Great Plains, migration to California, the Bonus Army march on Washington, and many other interesting situations. The students are fascinated by this peek into the past and it elicits all kinds of questions about life during the 1930's.

Another method of activating student interest is through writing assignments. The first essay assignment requires them to describe what life was like in the 1930's by finding someone who lived at that time and interviewing them. Many students are amazed to find that their grandparents lived during this time and can tell them fascinating stories of survival. Students are introduced to another world almost beyond their comprehension. It is a world of food from home gardens, family visits, and card playing, but no television, no cell phones, no credit cards, no trips to the beach, no jobs, and most importantly, no money. The second essay requires them to summarize the new ideas of John Maynard Keynes and explain how government intervention in the economy made for a better life in the rest of the 20th century.

My newest method of making economics more student-friendly is to arrive 15 minutes before class begins and play popular music by decade beginning with 1900-1910. "Don't Sit Under The Apple Tree With Anyone Else But Me" is a real contrast to some of the popular songs of today. I start the class by then showing them clothing fashions for men, women, and children for the decade of the music. As the music and fashions change, I ask them what is happening to the political and economic environment that is bringing about these cultural shifts. This leads to some very interesting discussions and provides an opportunity to talk about the shift from an agricultural to an industrial economy, the emergence of America as a world power, the changing role of women brought about by World War One and the 19th Amendment, the impact of electricity on industrial and home life, and many other changes.

When playing 1920's music I put my mother's 1927 high school graduation picture on the overhead and then thank the students for not saying anything derogatory about my mother. Oddly enough, this helps them connect to the material as it connects me to the era. I also tell them stories about my parent's life in the 1930's, as they were married in 1930. Their struggle to survive was complicated by the birth of both my brother and me during the 1930's. This provides an introduction to a class discussion on how their families would survive if another Great Depression occurred.

Microeconomics is more of a challenge to incorporate history as it does not begin with any significant historical event such as the Great Depression. Even so, I introduce the course by telling them of Adam Smith's 1776 book, *The Wealth of Nations* and how it influenced Thomas Jefferson in his drafting of the Declaration of Independence and the U.S. Constitution. From Smith's influence, Jefferson envisioned a country of small farmers and shopkeepers, equality and freedom of action for all, and no government intervention. This system prevailed and prospered in the agricultural economy until

the Civil War. Abraham Lincoln was the first president to have the government intervene in the economy with the Emancipation Proclamation, the Homestead Act, an income tax, paper money not backed by gold, and subsidies for the expansion of railroads. The railroads were the beginning of “big business” in America.

After covering supply and demand theory to explain the market system, I introduce production economics theory with videos about the Captains of Industry in the last third of the 19th century. These include John Jacob Astor, Cyrus McCormick, Cornelius Vanderbilt, Jay Gould, Andrew Carnegie, and John D. Rockefeller. All of these men provide fascinating stories of new technology, innovation, risk, and industrial growth. Urban industrial jobs were created as an alternative to working on the farm. It also is an important part of the story of the immigrants who arrived in America in the last three decades of the 19th century from eastern and southern Europe.

Later in the course I pick up this “big business” theme in the 20th century with Henry Ford and the development of the assembly line. Henry Ford got his inspiration from a meat packing plant disassembling animals for meat. Ford reasoned that automobiles could be assembled by reversing this process. Henry Ford’s first assembly line began with one worker pulling the automobile frame along with a rope while other workers along the line would assemble various parts until it was a complete car. Eventually, the mechanized assembly line employed millions of workers producing autos, home appliances, farm machinery, and many other products. This then provides an entry into labor economics and the rise of labor unions in the 1920’s and 1930’s, including union authorizing legislation as part of the New Deal. This in turn is a starting point for a discussion about income distribution. Another topic that attracts student interest is the origin of American leadership in innovation in the 20th century including electricity, telephones, transportation, the computer chip, and nuclear power. A variety of videos are available about the industrial revolution and 20th century technology.

Written assignments also provide an opportunity for students to increase their interest in economics. The first essay assignment requires them to select a product of their own interest and analyze the demand for it. This includes identifying who are the buyers (age, gender, income level), the price range and reasons for a range of prices, variations in the product (quality, brand names, design), and marketing methods (advertising, promotions). The second essay in the section on production economics requires the students to analyze the market structure for the production of a product. This includes the number and size of producers, methods of competition, research and development, innovation, and possible direction of the industry for the future. Students seem to develop a real interest in these writing assignments. The first allows them to think

more about some product that is very important to them. The second is often an opportunity for them to analyze an industry for which they have an investment interest. In both cases, we have interesting class discussions when I return the essays and single out the best ones for class discussion.

It is more difficult to use cultural changes in microeconomics. Yet, new technologies, both consumer and producer, offer opportunities to discuss the resulting cultural changes. I have often had very interesting discussions involving the changes brought about by nuclear energy, computers, calculators, cell phones, and automobile design. It is a challenge to make economics interesting to students. I have found that history, writing assignments, and cultural changes to be useful ways of making the introductory courses more interesting. It helps considerably if you have an interest in history yourself and are able to discuss the related historical periods with the students. It also requires that you acquire or have access to a collection of documentary videos and music CD's in order to illustrate historical perspectives. Writing assignments need not be so demanding but merely need to be designed to help the student relate their personal interests to economics. Using cultural changes is a more demanding way of connecting economics to the student. Yet the students are interested in music, fashion, and product innovation and design and will be inclined to discuss their perspective in class if given the chance. Teaching economics has been my life's work and I do gain great satisfaction from making it more interesting for my students.

UNDERSTANDING STUDENTS' DIFFICULTIES IN REASONING

Part One, Perspectives from Several Fields

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This is the longer text version of a 45-minute PowerPoint presentation at the AFACCT conference at Harford Community College on January 12, 2006. The handouts are incorporated here in a normal font as part of the narrative, with links to other versions of the handouts in more appealing formats.

I. HIGH SCHOOL PREPARATION

Results of 2002 National Assessment of Educational Progress

The results of the 2002 National Assessment of Educational Progress in writing were reported by the Department of Education in *The Nation's Report Card: Writing 2002* (2003). The assessment was administered to 19,000 12th graders at 7000 schools and included samples of narrative, informative, and persuasive writing.

ACHIEVEMENT LEVEL	2002 %	1998 %
Below Basic	26	22
Basic: The "writing should show some analytical, evaluative, or creative thinking. It should include details that support and develop the main idea of the piece. . . . The grammar, spelling, punctuation, and mechanics . . . should be accurate enough to communicate to a reader; there may be some errors."	51	57
Proficient: The writing should be "an effective and fully developed response . . . that uses analytical, evaluative, or creative thinking. . . . [S]tudents are able to use precise language and sentence structure to engage the audience . . . few errors in grammar, spelling, and punctuation, capitalization, and sentence structure."	22	21
Advanced: The writing should be "a mature and sophisticated response . . . that uses analytical, evaluative, or creative thinking. "	2	1

Source: National Center for Education Statistics, *The Nation's Report Card: Writing 2002*.
<http://nces.ed.gov/nationsreportcard/writing/results2002/>

Much worse were the results of the persuasive writing task, which requires critical thinking; 60% were below the Basic level. According to the Report (2003), "Persuasive writing . . . involves a clear awareness of what arguments might most affect the audience being addressed. Writing persuasively also requires the use of such skills as analysis, inference, synthesis, and evaluation."

Low Academic Literacy

A good deal of the research into students' ability to reason in their college courses suggests that they don't reason well because they haven't been taught to in high school. The National Assessment of Educational Progress (NAEP) for 1992 discovered that even the best students have great difficulty developing arguments using evidence and reasons. Four years later, the 1996 NAEP showed that most high school students do not read and write well. The percentage of high school students who arrive in college ready to learn independently from their textbooks is only 6 %. The percentage who writes well is even lower (2%) and those who write adequately is not high--less than a third (31 %).

Yet another body of research suggests that reasoning in college is closely linked to a variety of academic skills and that improving students' reasoning ability means improving their academic literacy--a holistic approach to solving a variety of problems caused by students' lack of preparation for college. According to Sherrie L. Nist of the University of Georgia, "Academic literacy is a term that is used to describe the skills and strategies that college students need in order to be successful in the courses they take. It covers reading, writing, listening, studying, and critical thinking processes." Nist's article "What the Literature Says About Academic Literacy" presents first the bad news (students haven't been taught the reading, thinking, and study skills they need) and then the good news: we can do something about it. Her article is summarized here (*Georgia Journal of Reading*, fall-winter 1993).

Nist's article points to ten differences in how the academic literacy expectations of college teachers differ from high school teachers:

1. Most high school students "enter college believing that learning is merely a compilation of facts. Students with such beliefs have problems in conceptualizing Such beliefs are especially true in courses such as history where high school teachers may have emphasized learning names, dates, facts, etc. at the expense on conceptualization. Certainly some memorization of facts is necessary at the college

level, but most courses require students to go beyond this basic level of understanding and thinking."

2. "Students are unprepared for the reading demands [of college] because they have not had to read in high school. When students come to college and expect to receive a rehash in lecture of what was presented in the text (as is often the case in high school), they have a difficult time adjusting."

3. Students are not taught explicitly in high school "how to carry out basic studying and note-taking procedures to meet college academic literacy demands. . . . What little they knew, they picked up instinctively. In addition, most students were surprised to discover that what worked in high school didn't work in college. [Even students with good HS grades] discovered that the study processes they used in high school were both inefficient and ineffective for getting good grades in college."

4. Even when college professors are quite clear about an academic task, students did not know what to do to produce what was asked. "Many waited until the night before to begin thinking about [a history essay exam question given a week in advance] then found they didn't really understand the question. Many more continued to memorize names and dates, although nothing in the academic task outlined by the professor suggested that this would be the correct thing to do. In short, students 'hung on for dear life' to what had worked for them in high school and then subsequently performed poorly on the test."

5. College teachers assume certain behaviors that students do not, in fact, have. High school students often have only to listen in class to do well on a high school test, yet college teachers assume that they have learned to take notes (which they haven't) and that they use them to study well (which they don't).

6. College teachers also assume that students have learned how to write answers to essay questions, when in fact they have written only multiple-choice tests in high school. In Nist's study, "Students often wrote essays that lacked supporting information, were poorly organized, and lacked analysis and synthesis--something that had been conveyed rather clearly by the professor. In fact, many of the students in the study had a distorted view of what an essay in this class should entail. They wrote three or four sentences and then wondered why they received only a small number of points, or . . . no credit at all."

7. "In terms of critical thinking, . . . even 'ambitious college-bound seniors' don't think about and interpret information in a discipline the way a college professor does."

8. "The way students study for and think about a discipline may be highly dependent on their epistemological views of learning. . . . How students define learning relates strongly to how they go about defining and pursuing academic literacy. . . . Students disproportionately define learning as memorizing and thus proceed to learn in this manner whether or not it is appropriate to the situation." Many students do not seem to know that they have taken surface approaches to learning; whereas their college professors are taking deep approaches.

9. "In general, students seem not to be metacognitively aware." Some students are unaware they don't understand something; others may be aware of "what they don't understand but don't know what to do about it. Many students go back and reread and reread information that they don't understand only to find that repeated re-readings help very little."

10. The level of cognitive tasks in high school is more often tied to standardized test criteria than it is to teaching students to think, analyze, and synthesize at higher levels. . . . Success in college is generally not tied to standardized tests.

Recommendations

1. Students need to be taught "to be active, strategic readers and learners." According to Elizabeth Chiseri-Slater, "Extensive and demanding reading is at the heart of most [college courses]. The close reading of texts, in fact, is an "assumed" college literacy skill, based on very little evidence of students' reading abilities, and with no guidance offered on how to accomplish this." (from *Academic Literacies: The Public and Private Discourse of University Students*, 1991)

2. "Students need to be taught a repertoire of study strategies (not skills)." They need to be taught how to think conceptually and how to problem solve.

3. "Students need to learn that writing is a tool that can be used to refine, synthesize, and reflect knowledge. Because students tend to be memorizers, they have a difficult time putting what they have read and heard into their own voice. . . . Many fail to note that much of the way they learn is through writing--taking lecture notes, isolating key ideas from a text, constructing strategies from which to study, being responsible for summarizing and paraphrasing."

4. Colleges must teach what high schools do not, rather than assume they have learned it.

5. "Much more needs to be done with teaching monitoring and metacognitive awareness."
6. "We need to think more about how motivation and other affective variables influence academic literacy."

Source: Sherrie Nist, "What the Literature Says About Academic Literacy," *Georgia Journal of Reading*, fall-winter 1993).

For more on teaching study strategies, see **METACOGNITION: Study Strategies, Monitoring, and Motivation** at the MCCCTR web site.

How do you as a disciplinary expert teach poor readers, writers, and thinkers to function well in your course?

Outlined below is a list of
Strategies for Teaching Critical Reading

1. Preview the assigned reading

- Summarize it in the previous class
- Ask interesting questions that will be answered in the reading assignment
- Take a poll on some of the issues addressed in the reading assignment
- Emphasize the interest, usefulness, and fit in the course sequence of the reading

2. Do not repeat the reading in a lecture

Do not make listening to your lecture become the student's reading strategy. It is tempting when students do not or can not read the textbook chapters to make sure the course content is "covered" by telling the students what they should have learned by reading the textbook. Among the reasons for not lecturing on assigned reading are

- Your students will not learn to read for comprehension--a valuable skill in your discipline.
- Your students will not learn to read critically--also a valuable skill in your discipline.
- Your passive learners will not learn how to **apply** the course information if the time they spend on task is spent on the tasks of listening and taking notes.
- Enough class time will not be spent on higher order thinking tasks, such as applying, conceptualizing, analyzing, synthesizing, classifying, comparing, and evaluating.

3. Have students write something in response to the text

Demonstrate how to do it; provide a model.

Write your daily instructions in the daily course syllabus.

- Outline or concept map
- Summary
- Ask/answer questions
- Read it twice, annotating then text as a believer and then as a doubter
- Write double-entry notes: one page (or column) for summaries of the text, and an adjacent page (or column) for comments
- Personal response

4. Design a focused, informal writing-to-learn task based on the reading

For example:

- Connect the reading to a past lecture or to prior knowledge
- Compare/contrast with another reading
- Critique/evaluate
- Apply the reading content to a scenario or case

For some suggestions for designing informal writing tasks that promote thinking, see the workshop on designing writing assignments that promote thinking, especially sections 7 and 8.

5. Monitor compliance

Develop ways to ensure that students do their homework without burdening yourself with daily feedback or recordkeeping.

See [A Strategy for Getting Students to Arrive in Class Prepared to Think](#)

II. PERSPECTIVES FROM THE FIELD OF CRITICAL THINKING

Students have difficulty doing the thinking we ask of them in our classes not because of low intelligence but because of their attitudes or thinking styles. Arthur Whimbey's study of characteristics of low-aptitude college students showed that they

- were mentally careless
- failed to read instructions carefully
- rushed through a problem ("one-shot thinking")
- didn't make a complete effort (quit too soon)

- were indifferent about their performance
- placed little value on reasoning as a way to solve a problem
- were more interested in the right answer than how to arrive at it

Source: Research by Arthur Whimbey, reported in Raymond S. Nickerson, David N. Perkins, and Edward E. Smith, *The Teaching of Thinking*. Laurence Erlbaum, 1985

Notice that "low intelligence" is not among the characteristics.

Thinking well is often a matter of attitude or disposition, rather than intelligence. Robert Ennis has devised a well-known list of dispositions for critical thinking. It is not enough to teach students to perform thinking operations and tasks, says Ennis. They should also be taught the attitudes and willingness to carry them out on their own, unasked.

Critical Thinking Dispositions

Seek a clear statement of the thesis or question

Seek reasons

Try to be well informed

Use and mention credible sources

Take into account the total situation

Try to remain relevant to the main point

Keep in mind the original or basic concern

Look for alternatives

Be open-minded

Take a position (and change a position) when the evidence and reasons are sufficient to do so

Seek as much precision as the subject permits

Deal in an orderly manner with the parts of a complex whole

Use one's critical thinking abilities

Be sensitive to the feelings, level of knowledge, and degree of sophistication of others

Source: Robert H. Ennis. "A Taxonomy of Critical Thinking Dispositions and Abilities" in *Teaching Thinking Skills: Theory and Practice*; eds. Joan Boykoff Baron and Robert J. Sternberg. Freeman, 1987.

Notice that these are skills and attitudes that can be taught daily and explicitly. Students' dispositions to think critically can improve over their college years. An 8-step procedure for modifying students' behavior, attitudes, and motivation has been designed by Dr. James Bell of Howard Community College.

Limitations Because of Thinking Style, Know How, Etc.

What limits thinking?

There are several ways of diagnosing students' difficulties in carrying out the reasoning process we ask them to undertake. A book titled *The Teaching of Thinking* has a handy list:

Problems with Thinking and Learning Style

- Not having traits such as attentiveness, precision, persistence, resourcefulness, orderliness, etc. (See characteristics of low-aptitude college students, above, and dispositions for critical thinking, above.)

Problems with Know How; Making errors in encoding, operations, and goals:

- Errors in Encoding

Missing important data or not separating relevant from irrelevant data. For example, some students in classes in writing about literature will base their interpretation of a poem on just the first stanza.

- Errors in Operations

Failing to select the right subskills to apply

Failing to divide a task into subparts. For example, some math students will jump right to what they think is the final calculation to get the desired answer.

- Errors in Goal Seeking

Misrepresenting the task. For example, students in a speech communication class instead of doing the assigned task of analyzing and classifying group communication strategies in their group discussion will instead just write a narrative of who said what. Researchers at Carnegie Mellon University have investigated how students interpret college academic writing tasks' discovering that sometimes students did not engage in the critical thinking that the professors' assignments intended (Flower (1987); Nelson (1990); Kantz (1989).

Not understanding the criteria to apply. For example, when asked to evaluate the support provided for the major claim of an article, students will explain why they liked the article rather than apply appropriate judgmental criteria.

Problems with Cognitive Load

- Too many subskills necessary to do a task. For example, some students have not yet learned how to carry out all the steps in a complex nursing procedure.
- Not enough automatic, internalized subskills. For example, students have to look up their notes on how to analyze evidence in an argument because they have not internalized the procedure.

Problems with Abilities

Lacking the level of needed mental abilities. For example, students are asked to think abstractly about general concepts and issues, but they can only think concretely about specific situations

Source: Raymond S. Nickerson, David N. Perkins, and Edward E. Smith. *The Teaching of Thinking*. Erlbaum, 1985.

A good way to discover what kind of errors students are making in their thinking processes is to get them to unpack their thinking, to tell you step by step how they are going about the task. By listening to how they are solving the problem, an instructor can detect where the student is going wrong. Asking students to describe their thinking processes develops their metacognitive abilities—a very necessary skill to improve thinking.

III. PSYCHOLOGICAL RESISTANCE TO THINKING

If thinking well is such a good idea, why isn't everyone doing it? Answer: There are sometimes psychological barriers to clear thinking, even in those who are trying to be effective thinkers.

Enculturation, Ego Defenses, and Inaccurate or Incomplete Schemata

Most general textbooks intended for critical thinking courses open with a brief section challenging students to confront their hidden obstacles to good thinking. **Enculturation** (the process of acquiring the basic beliefs and values of one's culture) provides a primary obstacle to thinking about new ideas. It is impossible for students not to be influenced by their economic class, location, schools, race, customs, and family. Their attitudes about romance, marriage and divorce, work ethic, patriotism, what it means to be a man or woman, religion, authority, outsiders, insiders, social change, education, conformity, and dozens of others of their beliefs have all been formed by these influences.

How does enculturation interfere with our students' thinking?

People tend to fear ideas that oppose or challenge their sense of identity. Because enculturation has shaped their identity, they are likely instinctively to resist ideas that threaten their self-concept. Students, like everyone else, perceive what they want to see—especially when it preserves their self-image and sense of identity. In a science class you might have religious students who have acquired the belief that science and faith are enemies. They might resist becoming comfortable with the assumptions of scientific procedures that challenge their upbringing. Students whose high school experience has taught them that significant learning is memorizing facts presented by teachers will believe that working in small groups is a waste of time.

Ego defenses such as denial and rationalization are coping strategies that protect ourselves from anxiety, guilt, and other bad feelings. Doing poorly on a test and then blaming the test or the instructor is a way of denying that the real cause was poor study habits, low motivation, or lack of preparation. Not persevering in reading difficult material because it makes you feel stupid is another example.

A **schema** based on misperceptions, wrong information, and incomplete information can also interfere with accepting new or contradictory facts and ideas. A **schema** (the plural form is **schemata**) is one's understanding of something based on your previous information and experience. For example, students have **schemata** of photosynthesis, algebra, marriage, Buddhism, Germans, justice, critical thinking, killer bees, immigrants, roses, labor unions—all based on a combination of all that they have heard, seen, and accepted from the mass media, family and friends, school textbooks, the playground and workplace, authorities, whatever. As the [Sherrie Nist](#) article (above) pointed out, students often have a misconception that significant learning means memorizing, not learning to reason about alternatives.

Coping with Student Resistance to Reasoning

An article in *College Teaching* sees an analogy between patients' resistance to personal growth through therapy and college students' resistance to intellectual growth through independent thinking. According to Keeley and his co-authors, teachers need "to recognize and overcome students' natural resistance to learning to think critically, a process that requires considerable behavioral change" (140). Believing that in several important ways the instructor/student relationship and psychotherapist/patient relationship is similar, the authors find good suggestions for teachers in psychotherapy literature. One similarity, for example, is the discrepancy between a student's (or patient's) wish for the expert teacher (or therapist) to provide single right answers and the teacher's wish that the students pursue their own investigations with a lot of hard work, coming to their own solutions. The behavioral changes needed to think critically require in the student a desire to change and the ability to endure frustration. It requires self-confidence in order to try techniques they are not good at and risk failure; it likewise takes self-confidence to rely on one's own thinking, rather than on an expert's.

Among their tips for professors:

1. Create credibility and classroom security by establishing your expertise. Secure leadership in the classroom can be established by good communication skills; for example, appearing interested, talking at the students' level, and being articulate and well-prepared.
2. Create a supportive rapport by being empathetic, communicating your respect for students; acting genuinely, and listening actively.
3. Create a climate where students feel they can take risks.
4. Be aware of students' expectations about teaching and learning; change those expectations when appropriate. For example, find out if students expect you to lecture--especially if you intend to use inquiry methods for students to obtain their own knowledge. Explain how your teaching methods might be different from what they are used to.
5. Handle homework assignments effectively. Homework that requires time and self-discipline is typical of classes that encourage critical thinking. Prepare students to meet your demands by showing them the techniques they need to employ to succeed. Make instructions clear and within student's capabilities.
6. Recognize signs of student resistance. Examples: "students either clowning around or monopolizing discussions, excessive complaining, passive withdrawal, missing classes

or skipping assignments, and inappropriate emotional dependency" (143). Take a problem-solving approach to these cases, rather than personalizing them. Don't blame yourself.

7. Encourage students to discuss their resistance.

Source: Keeley, Stuart M., Kenneth M. Shemberg, Brenda S. Cowell, and Brian J. Zinnbauer. "Coping with Student Resistance to Critical Thinking: What the Psychotherapy Literature Can Tell Us." *College Teaching*, v. 43, no. 4 (Fall 1995), 140-145.

IV. LEVELS OF INTELLECTUAL GROWTH

Two influential studies of how college students develop personally and intellectually provide a good deal of insight into the steps students take as they become mature thinkers. In the process outlined by both William Perry and by Mary Belenky and her associates, personal and intellectual growth comes in stages over time—and it doesn't always come easily. Students in one stage sometimes will have difficulty before settling into the next stage.

How do your students usually deal with two-sided issues in your discipline? Do they choose the side backed by what they learned from authorities (parents, teachers, or religious leaders)? Do they feel that both sides are "just opinions" and equally right? Are they aware of the reasons and evidence that support both sides on a complex issue and assessed the support for both points of view? Have they chosen their own position after assessing both sides?

On the abortion issue, for example, consider the different levels of intellectual complexity and emotional engagement in the following questions. (1) Do students automatically adopt the position of their religious authorities or favorite political organizations? Do they see themselves emphatically on the right side, pitted against evildoers on the opposite side? Or (2) do they feel that all Americans have the right to their own opinions, and both sides are correct on the abortion issue? Do they believe there are two sides to every question, and it doesn't make any difference what side someone takes? Or (3) do they feel that one's position on the abortion issue depends a great deal on the definition of when a fetus becomes a person, and that this definition is not fixed or determined by a single expert authority. Are they aware of disagreement in the medical communities about these issues? Are they aware of differing ethical views about which issues should have priority: ethical issues affecting the pregnant woman and her family and social relationships or ethical issues affecting the fetus? Have they assessed the evidence and reasoning used by both sides of the abortion issue? Or (4) have they taken a position on the issue after a difficult emotional struggle because they fully considered the powerful emotional, moral, and practical concerns on both sides?

These questions illustrate four levels of complexity in dealing with intellectual and ethical issues. The first two levels of questions are easy to handle because students' minds at that level of intellectual growth quickly reach closure on the issue, avoiding a struggle between rival ethical and intellectual reasons. Reaching early closure on an issue is psychologically comforting because they avoid the stress of dealing with contradictions (see, the section above on psychological resistance to thinking). But early closure and a rush to judgment also prevent a full understanding of a complex issue such as abortion or rival approaches or theories in your disciplines. And the easy way of uncritical thinking retards one's intellectual growth. Your courses, I hope, encourage your students to take the more difficult path of genuinely considering both sides of an issue, accepting the emotional stress that accompanies genuinely identifying with opposing views.

As your students become self-directed, reflective practitioners of critical thinking and disciplinary reasoning, they will become increasingly aware of the complexity of knowledge and the need to recognize that no knowledge is definitely "true." This awareness develops in stages. The two most influential models of intellectual development in recent years are described by W. G. Perry, Jr. (1970) in *Forms of Intellectual and Ethical Development in the College Years: A Scheme* and M. F. Belenky, B. V. Clinchy, N. R. Goldberger, and J. M. Tarule (1986) in *Women's Ways of Knowing: The Development of Self, Voice, and Mind*. Both books chart intellectual development from a beginning position of accepting factual knowledge from authorities without questioning either the facts or the authorities. The highest stage is commitment to a position that you have arrived at through genuinely considering opposing views, examining personal experience, and engaging in personal reflection, without relying on the assurance of external authorities.

The Perry Scheme

Perry began interviewing first-year students at Harvard in the mid-1950s to study how students dealt with intellectual and moral relativism; he continued for about 10 years, interviewing many of the same students each year during their 4-year stay at Harvard. To avoid structuring the students' answers by how the researchers phrased the interview questions, he and his staff began the interviews with the open-ended question, "Would you like to say what has stood out for you during the year?" They followed the students' responses with, "As you speak of that, do any particular instances come to mind?" (Perry, 1970, p. 7).

From their answers Perry discovered that many students had passed through the same stages of intellectual development. Based on a careful analysis of their tape-recorded

interviews, he constructed a map of their intellectual journey, now called the Perry scheme. Perry describes nine positions through four basic stages: Dualism, Multiplicity, Relativism, and Commitment.

Dualism At this stage of intellectual development, one is very certain of what one knows and of what makes it true. All questions have a single right answer and the authorities will tell you what that answer is. Dualists are passive learners; in their view the only appropriate response to course knowledge is to memorize it because the textbook and professor are the authorities; therefore, their knowledge must be true. The only appropriate response to ethical issues of right and wrong is to find out what the authorities say about it (church, parents, the state). None of the college students were at this stage when Perry and his staff interviewed them at the end of their first year--but some had begun their first year at this stage and gave it up during their first year of college as they became less dependent on authorities and more independent in their thinking.

Multiplicity Sooner or later, one must give up the comfort of certainty for the realization that not everything is known, even by the experts. In some areas it must be acknowledged that there is no single known truth. The attitude of students during the multiplicity stage is "Everyone has a right to his own opinion" and "Where authorities do not know the answer, my opinion is as good as any other" (Perry, 1981, p. 84). The belief at this stage is that no opinion can be wrong, that any moral principle is as right as any other. Multiplists see no point in criticizing other points of view because it doesn't make any difference--all opinions are equally valid. At the multiplist stage, the lessening of devotion to authority is an advance from dualism into independent thought, and the egalitarian respect for others' views is also an advance. But the multiplist's attitude uncritically levels all opinions without distinguishing between more valid or less valid reasoning.

Relativism Some other commentators, but not Perry, use the term *relativism* to describe the stage that Perry calls *multiplicity*--the uncritical acceptance of all points of view without considering the evidence and reasoning that supports them. As Perry uses the term, **relativism** is the stage where one recognizes that there are several approaches to an issue, that these approaches are not of equal validity in all situations, and that the context has an effect on the validity of knowledge and a way of knowing. The relativism stage is an intellectual and ethical advance over the automatic acceptance of any personal opinion (the multiplicity stage). At this stage, students come to understand several points of view by analyzing the thinking processes displayed, by examining the use of evidence and reasoning. And also at this stage they judge those points of view and the thinking that supports them. At the previous multiplicity stage they

automatically accepted them, without judgment. At the relativism stage, students understand the importance of learning procedures and criteria for judging some viewpoints as better or worse, for assessing how well some writers support inferences, for determining whether one view explores consequences more deeply than another, for approving the higher moral principles of one viewpoint over another.

But employing the procedures and criteria of the relativist can leave one longing for the deceptive certainty of authorities and the single one right answer of the dualist stage. In the students' interviews, Perry heard students sometimes back away from the psychological risks and uncertainties of the relativist stage. When students became too psychologically uncomfortable with the decisions made available at the relativist stage, Perry discerned three ways of avoiding intellectual growth: temporizing, retreat, and escape. **Temporizing** means postponing a commitment to a decision between alternatives. An example of temporizing is to wait a little longer to take a position on such complex social issues as abortion, affirmative action, or assisted suicide; or to not vote in the next election, rather than take a stand on the current political candidates--especially if taking a stand might cost the student someone's goodwill or go against the way he or she was raised. **Retreat** is Perry's term for returning to the dualist stage, usually with allegiance to an all-or-none, we-against-them, extreme position of right against wrong. Students retreating to the dualist stage needed an enemy; they were full of complaints about the side opposite to their own. In the interviews, the students in retreat railed against professors who wouldn't tell them exactly what position to take in their term papers. **Escape** is another form of alienation that avoids dealing with the complexity and uncertainty of the relativist stage. Sometimes the awareness of diverse approaches leads to a paralysis of decision making; some students drifted from major to major, never committing themselves to a single course of study. Others kept learning the knowledge of experts, never taking a position of their own on the issues they read about. Their escape was to stay in the relativism stage, avoiding the commitments and postponing making their own meanings.

Commitment Making choices and decisions after the reasoned explorations of the relativist stage is the next developmental step. An example of the commitment stage is choosing a position on controversial ethical issues (for example, abortion, assisted suicide, affirmative action) based on values you have chosen after considering the moral complexity of the issues--rather than choosing based on the values that were handed to you by authorities or enculturation. For the college students, the choices at the commitment stage also involved choices of majors, careers, and relationships.

Another realization made by many students at the commitment stage is that there is no final stage. Intellectual and ethical development is a recursive process. It repeats itself.

As Perry, puts it, "Indeed the development we have traced in college students reveals itself now as 'age-free'" (Perry, 1981, p. 97). Issues never really get settled; new knowledge replaces old; the context of knowledge and values changes.

You can exhibit all these stages at one time, depending on the area of thought. Advancing to the commitment stage in one area of thought does not mean that you have reached that stage in all areas. For example, in the areas of disciplinary reasoning, you are probably at the commitment stage. You have read the experts, noticed where they disagreed, examined their evidence and reasoning, and made up your own mind. You selected what to emphasize in your course and decided what to leave out. But while at the commitment stage with disciplinary theory, when I first encountered Windows 3.1, I was a dualist. I relied completely on authorities (a guidebook I bought and my expert son), refused to experiment or press any key not designated by the guidebook or my son, and wanted a list of written rules and keystrokes to follow for every application. In general, one can move through the stages of the Perry model as one acquires the knowledge and experience to assess claims and to make independent judgments.

PERRY'S SCHEME OF COGNITIVE AND ETHICAL DEVELOPMENT (summarized)

DUALISM

Division of meaning into two realms:

Good vs. Bad, Right vs. Wrong, We vs. They.

Right Answers exist *somewhere* for every problem, and authorities know them. Right Answers are to be memorized by hard work.

MULTIPLICITY

Diversity of opinion and values is recognized as legitimate in areas where right answers are not yet known. Opinions are atomistic without pattern or system. No judgments can be made among them so "everyone has a right to his one opinion; none can be called wrong."

RELATIVISM

Diversity of opinion, values, and judgment derived from coherent sources, evidence, logics, systems, and patterns allowing for analysis and comparison. Some opinions may

be found worthless, while there will remain matters about which reasonable people will reasonably disagree. Knowledge is qualitative, dependent on contexts.

COMMITMENT

An affirmation, choice, decision (career, values, politics, personal relationship) made in the awareness of Relativism. Agency is experienced as within the individual.

Perry also discovered that students at the Multiplicity stage used three different ways to avoid intellectual development to a more uncomfortable higher stage:

- Temporizing: Postponement of movement for a year or more
- Escape: Alienation, abandonment of responsibility. Exploitation of Multiplicity and Relativism for avoidance of Commitment
- Retreat: Avoidance of complexity and ambivalence by regression to Dualism colored by hatred of otherness

SOURCE: William G. Perry, Jr. "Cognitive and Ethical Growth: The Making of Meaning." In *The Modern American College: Responding to the New Realities of Diverse Students and a Changing Society*, edited by Arthur Chickering and Associates. Jossey-Bass, 1981.

Belenky et al.: *Women's Ways of Knowing*

Mary Field Belenky and the other three women who worked with her studied a very different population than William Perry's subjects. Perry interviewed only male students at Harvard University from 1954 to 1963; Belenky et al. (1986) interviewed only women, mostly from colleges but also from family agencies, in the late 1970s. Thus Belenky's group studied women in a much broader range of social classes and ethnic backgrounds. Although Perry's study was designed very well to study intellectual and moral development in its male subjects, Belenky et al. write that "it was poorly designed to uncover those themes that might be more prominent among women. Our work focuses on what else women might have to say about the development of their minds and on alternative routes that are sketchy or missing in Perry's version" (p. 9). When Belenky et al. began to classify their data, it did not "fit so neatly into his categories" (p. 14). Whereas Perry's scheme sees a linear progress from position to position, Belenky et al. did not discover the same stage-to-stage sequence in the intellectual movement of the women they interviewed. Rather, from listening to their subjects' stories, Belenky et al. constructed five perspectives on knowledge that these women held, noting that at some points in their lives they shifted from one perspective to another. Still, the Belenky et al. observations about intellectual and moral development in women have many similarities to Perry's.

Silence Among the women they interviewed, the feeling of being "mindless and voiceless and subject to the whims of external authority" (p. 15) was rarely observed and was held only by some of the youngest and most deprived of those interviewed. These women had grown up in isolation subjugated by authoritarian figures, not exploring their potential for speaking their own minds.

Received Knowledge This perspective is much like the dualistic position in Perry's scheme. Knowledge comes from authorities, not from oneself or peers. Authorities are the sources of truth and know the single right answer for each problem. Those who took the perspective of received knowledge believed in a sharp dichotomy of right and wrong, a belief typical of dualistic thinkers, and they accepted the pronouncements of authorities (parents, teachers, religious leaders, laws)

Subjective Knowledge Subjective knowledge is a "conception of truth as personal, private, and subjectively known or intuited" (p. 54). Knowledge from external authorities is rejected in favor of an intuitive feeling that something is so. This move towards autonomy, independent thought, and inner strength is an advance over silence and received knowing. Often the subjective knower still contains characteristics of the two earlier positions: dualist and absolutist notions of right versus wrong, although in the subjective knowledge perspective these concepts come from within. "I just listen to the inside of me and I know what to do" (p. 69) is a characteristic comment by subjective knowers. Women who maintain this extreme subjective position are at a disadvantage in college and workplace, where objectivity and rationalism are valued.

Procedural Knowledge Women who decide to rely on procedures, criteria, and reasoned judgment are rejecting subjectivism. Some of the women college students reported that in some ways it felt like a return to obeying the voice of authority--obeying the expert professor telling them how to think in the course. But knowing how to analyze, how to follow a disciplined method, and how to be objective gave them a sense of empowerment and control that felt like independent thinking, as indeed it was.

Constructed Knowledge The final perspective in the Belenky et al. model is analogous to Perry's final position in that both models place the highest value on knowledge gained by one's own search for meaning, both models recognize the importance of context, and both models acknowledge the relative and uncertain nature of truth. "To see that all knowledge is a construction and that truth is a matter of context in which it is embedded is to greatly expand the possibilities of how to think about anything" (p.138). From a perspective that acknowledges the importance of the context, asking questions about the context becomes a crucial method of inquiry: Who is making a claim? why? in what context? how are various answers judged?

FIVE PERSPECTIVES ON INTELLECTUAL DEVELOPMENT (Summarized)
from WOMEN'S WAYS OF KNOWING

SILENCE

A position in which women experience themselves as mindless and voiceless and subject to the whims of external authority;

RECEIVED KNOWLEDGE

A perspective from which women conceive of themselves as capable of receiving, even reproducing, knowledge from the all-knowing external authorities but not capable of creating knowledge on their own;

SUBJECTIVE KNOWLEDGE

A perspective from which truth and knowledge are conceived of as personal, private, and subjectively known or intuited;

PROCEDURAL KNOWLEDGE

A position in which women are invested in learning and applying objective procedures for obtaining and communicating knowledge;

CONSTRUCTED KNOWLEDGE

A position in which women view all knowledge as contextual, experience themselves as creators of knowledge, and value both subjective and objective strategies for knowing.

Source: Belenky, M. F., Clinchy, B. V., Goldberger, N. R., & Tarule, J. M. (1986). *Women's Ways of Knowing: The Development of Self, Voice, and Mind*. New York: HarperCollins, p. 15.

[Note: Much of the material in Section IV, Levels of Intellectual Development, is slightly modified from material I wrote for the University of Maryland University College Course Guide for ENGL 396, Critical Analysis in Reading and Writing.]

Promoting Growth to Higher Stages of Intellectual Development

Both the Perry and Belenky models of intellectual growth present as a final position the mature thinker who seeks to understand the full context of an issue to make up his or her own mind. The way to help students reach this stage is by presenting them with several views: What Richard Paul calls dialogical thinking. Determining knowledge for

yourself is a dialogical process that analyses the evidence and reasoning presented in opposing arguments, fully considers opposing values, becomes aware of conflicting disciplinary methods of inquiry, assesses the reasoning of experts who disagree, and explores opposing worldviews. Active learning strategies that explore two-sided issues promote intellectual growth.

For some suggestions for designing informal writing tasks that promote thinking, see the workshop on designing writing assignments that promote thinking, especially sections 7 and 8.

V. PERSPECTIVES FROM GENDER DIFFERENCES

Is there anything inherent in academic discourse that makes a student's gender a relevant issue? Will a student have difficulty just because she's a woman? According to several scholars, yes.

Carol Huber, addressing a conference on inquiry across the disciplines, "The thesis-driven argument, the primary form of academic discourse, . . . is incompatible with most female students' preferred style of learning." It is also the basis of Western male-centered educational institutions since the classical Greek academy (see also Walter Ong; Janice Moulton in the list of resources, below.)

Several researchers (e.g., Carol Gilligan; Paula Treichler & Cheri Kramarae, Elizabeth Chiseri-Slater) have written that women are alienated by higher educational institutions. Women students are uncomfortable with the combative model of debate where "women are expected to be publicly assertive authorities who challenge the intellectual views of others" (Elizabeth Chiseri-Slater). Women, according to these researchers, prefer using reasoning to understand issues and to persuade open-minded people—not to defeat adversaries or prove them wrong.

Separate and Connected Knowing

One of the Belenky group's observations was that "women often feel alienated in academic settings and experience 'formal' education as either peripheral or irrelevant to their central interests and development" (p. 4). What Belenky's group discovered that Perry did not is the distinction between two kinds of procedural knowledge: separate knowing and connected knowing. Women present a variation on Perry's model in that they wish to connect with the knowledge of another person, "to enter the other person's frame to discover the premises for the other's point of view" (p. 101). On the other hand, separate knowing is "based upon impersonal procedures for establishing truth" (p. 102).

Connected knowing is based on empathy, on trying to experience another person's point of view through his or her thinking process. Belenky speculates that more men may prefer separate knowing and more women may prefer connected knowing, but she acknowledges that her study has not developed hard data on this subject.

What Belenky et al. did discover is that many women in college did not prefer the typical separate-knowing procedure of coldly analyzing a logical argument. The stance of the skeptical critic ferreting out something wrong in a logical argument is an adversarial form of debate reasoning that many women did not automatically enjoy the way men seemed to. Women became adept at playing the debate game, but many considered debate and detached analysis an empty exercise.

More fruitful for many women were procedures for connected knowing, for postponing judgment, for empathetically seeing through the perceptual lens through which other thinkers viewed an issue. Collaborative learning and collaborative exploration were preferred forms of procedural knowing among many of the women interviewed.

"Women apparently are less concerned with proving opponents in error than with changing their thinking" (Huber, p. 350). The problem with informal logic courses and similar kinds of critical thinking courses is their "emphasis on analysis and assessment of arguments advanced by others" and defending one's position. The emphasis on defending a position encourages a rush to closure and puts the reader of your argument into the position of agreeing or disagreeing. Women prefer active questioning, understanding opposing views, and understanding why people think that way. They would rather change the minds of neutral readers than oppose dogmatists.

Pedagogical Strategies that Encourage Women's Reasoning

According to Chiseri-Slater (1991), *Academic Literacies: The Public and Private Discourse of University Students*, the pedagogical strategies that promote inquiry and connected knowing and that women are more likely to see as encouraging their intellectual development are

- Small group tasks that explore varying views
- Student-led discussions
- Journal writing, especially reader responses
- Double-entry journals that record summaries of texts on one page of a notebook and personal reflections on the texts on an opposite page
- Other dialogical inquiry and reasoning tasks

As it happens, these strategies also improve the reasoning skills of men.

VII. CONCLUSION

So, what have we learned?

We have learned that students come to our courses with many understandable reasons for having difficulty doing the reasoning tasks we ask of them:

1. Their high school preparation has taught them that memorizing the correct answer is how to succeed in school and has not taught them the reading, writing, and techniques that do promote success. They have misconceptions about significant learning.
2. They may lack the dispositions or thinking styles and procedures for doing the reasoning we ask of them.
3. They may have psychological barriers or resistance to inquiry methods of learning.
4. They may not have developed intellectually to a level that is comfortable with opposing views and no single right answer.
5. Women may be alienated by the adversarial discourse of academe.

And we learned that a variety of teaching strategies can help our students, from teaching note-taking techniques to using a full range of active learning strategies.

[Click here](#) to read *Understanding Students' Difficulties in Reasoning, Part Two: The Perspective from Research in Learning Styles and Cognitive Style*.

For further reading, check out the resources listed below, which include the references cited in this document. You might want to check out the series of handouts of the workshop on [designing writing assignments that promote thinking](#), and the additional [Resources for Teaching Thinking](#) and the [links to other web sites](#) for teachers of thinking.

RESOURCES FOR UNDERSTANDING STUDENTS' DIFFICULTIES IN REASONING

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To the Annotated List of Documents from PGCC

TRUTH AND VALIDITY IN CRITICAL THINKING

Nicholas Plants
Philosophy

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Recall for a moment how many times your teachers told you (and how many times you have told your students) that truth is good and assumption bad. It is ironic that in education, where so much time is spent pursuing truth and debunking assumptions, truth may obstruct learning and assumption promote it. Such is often the case, however, especially in the very province where you might think it would be least likely—logic, and by extension, critical thinking.

Logic is often defined as the study of methods for evaluating whether the premises of arguments adequately support their conclusions. Although by no means limited to logic, critical thinking is closely aligned with it because logic's methods for evaluating whether the premises of arguments support their conclusions are themselves paradigmatic instances of critical thinking. Logic's methods of evaluation foundationally inform much of critical thinking for this very reason.

One notable exception is when critical thinking is taught in such a way that the truth of a passage is emphasized at the expense of its validity. Although not all the passages we who teach critical thinking present to our students are arguments, many are, and in such cases it is crucial for us to ensure that logic's methods of evaluation are properly employed. Doing so requires fluency in logic no less than in critical thinking.

One of the most significant distinctions in logic that we must be conversant with to ensure that our students are thinking critically is the distinction between truth and validity. Logic's method for evaluating whether the premises of an argument support their conclusion is not limited to assessing whether they are true. For in order for the premises of an argument to support its conclusion adequately, the reasoning process by which these premises are linked to their conclusion must be valid, that is, follow necessarily. If in addition to being valid an argument's premises are all true, then it is termed a sound argument.

Because this distinction between truth and validity is not at all an intuitive one, however, the tendency among teachers and students alike is to focus on the more readily apparent of the two: truth. Doing so leads to passages being assessed on the basis of whether their content is true. So if the content of a statement is capable of being evaluated in terms of truth, and is determined to in fact be true, we happily move onto the next statement. If it too is true, we tend to believe this second statement must

combine with the first into a passage which, having thus been critically assessed, we are cheery to identify as wholly true. During such an assessment critical thinking regarding truth occurs, as we must rightly identify whether the content of all the statements within a passage is true.

But content alone does not, and cannot, determine the validity of arguments. For it is fully possible for a passage to consist of premises and a conclusion that are all true and for it to still be invalid. So critical thinking regarding validity and not only truth is required in order for critical thinking to be properly informed by logic. Validity matters because true premises by themselves do not make good arguments. And so the question of whether the premises of an argument are all true is clearly distinct from that of whether an argument is valid. Even if its premises and conclusion are both true an argument may well be invalid, as surely as an argument with false premises and a false conclusion may well be valid. Validity also matters, therefore, insofar as it preserves truth—if you begin with true premises and reason validly you will secure a true conclusion.

If critical thinking is taught in such a way that truth plays a dominant role, however, it is likely that passages identified as true will ironically be complicit in the advancement of invalid reasoning. Such is a case in which truth ironically obstructs learning rather than promoting it. As teachers we must not countenance any such advancement of invalid reasoning, even in the name of critical thinking regarding truth. The best way to avoid doing so is, ironically enough, to turn to the power of assumption for help in promoting critical thinking regarding not only truth but truth together with validity.

Logic's method for evaluating whether or not the premises of an argument adequately support their conclusion is to first assume its premises are true and then determine whether the conclusion necessarily follows. If the conclusion follows from the premises necessarily, regardless of whether the premises are true, the argument is valid. If the conclusion does not follow necessarily, even if the premises are all true, then the argument is invalid.

Once the validity of an argument has been evaluated on the basis of assuming its premises to be true then the question of whether its premises are in fact true can be assessed. If the premises are true and the argument is valid, then the argument is sound. If the premises are false then even if the argument is valid, it is not sound. If the premises are true but the argument is not valid, then the argument is not sound. Regardless of which of these permutations holds, it is the initial assumption that its premises are true that enables us to determine whether the argument is valid. Thus assumption ironically promotes learning in the sense that it enables us to teach, and

students to learn, that critical thinking regarding validity is no less crucial than regarding truth, and is only at its best when it regards both.

For teachers, working against the tendency to focus on truth more than upon validity is no less crucial a task than it is for our students. Given that we are their teachers, it is even more crucial a task for us. One way to promote the accomplishment of this task is, as we have seen, to turn to assumption so that we might first evaluate whether an argument is valid before we determine whether its premises are true. As noted above, the tendency to do the reverse, and determine its premises to be true first, only to then disregard the question of its validity altogether, is related to the tendency to focus on content more than form.

One way to counteract this related tendency is to stress that form must first be isolated in order for content to be properly assessed. Isolating the form of arguments is difficult because it requires students to transpose content into symbols, and so requires a degree of abstract reasoning akin to mathematics. Here lies another barrier to evaluating whether the process of reasoning whereby premises are validly linked to conclusions, as students must if they are to determine whether arguments are sound. Unlike assessing the content of passages, which is a decidedly concrete procedure, evaluating their form is much more abstract an affair, one that students commonly avoid, even though they do so at their own peril. Although difficult, inspiring them to reverse their tendencies by beginning with abstract form and only then moving onto concrete content is a transformative reversal we teachers discount at our peril.

Similarly, unlike the content of arguments which are unique to specific disciplines, their forms underlie all content, and so are notably flexible. It is often objected against logic that it is unique to philosophical inquiry and correspondingly much too rigorous to inform critical thinking, which requires flexibility above all else. It is true that critical thinking must be flexible enough to accommodate all disciplines, not just logic. But it is equally true that critical thinking will best accommodate all disciplines when it is informed by logic, and more specifically, by its insistence that form must be isolated before content is assessed as the best way to establish both truth and validity.

Once a valid argument form has been isolated it is possible to consistently substitute any content, regardless of its specific discipline, and thus secure a sound argument. Just as validity is more difficult to evaluate than truth, isolating argument forms is more difficult than assessing the truth of the content they contain. The benefit of first isolating an argument's form, just like that of first evaluating its validity, however, pays immediate dividends, as the validity of a form is much easier to evaluate if the form has

already been isolated, which it will be, provided that validity is emphasized prior to truth.

A final distinction, uniquely significant for teachers of critical thinking, is analogous to that between truth and validity and content and form: the result and process distinction. No less than our students, we teachers tend to focus on truth more than validity, and thus on content more than form. We do so because of an even stronger tendency that is often unique to teachers--the tendency to focus on the results, more than the process, of teaching. "Teaching to the test" is likely the most noted example of this tendency, though it can be evidenced by phrases as common as "covering" the material or "following" the syllabus. Regardless of the specific phraseology, the truth is that it is not only possible, but common, for teachers to emphasize the result of successfully conveying a given body of knowledge at the expense of the process whereby students learn. It is remarkably easy to be so fixated on achieving the result of a group of students who are "where they should be" at the semester's end that teachers may ironically lessen the process that they, and we, participate in so as to perhaps get them there.

Just as it is possible to ironically enable invalid reasoning by being overly focused on the truth, it is possible to ironically lessen the process whereby we teach by being overly focused on its results. What is crucial at the end of the day is not simply the content of what we convey anymore than it is the result of having done so—it is our having engaged, together with our students, in the formal process of valid reasoning whereby any result, especially including the truth, is secured. Such reasoning is not properly result-driven, though it boasts positive results, nor is it content-driven, although it clearly requires content: it is a formal process that is both flexible and rigorous enough to properly evaluate the conclusions through which all disciplines express their various truths. As teachers, it is not simply our charge to make sure that our students can assess these claims but, more importantly, that they might first evaluate whether they are valid so that, when true, such claims will be neither true alone nor valid alone but rather both true and valid, that is, sound. The only result we must aspire to is engaging our students within this process.

WRITING PROMPTS FOR MA XXX – Poese

Each week you will be asked to write a brief response to a question or statement I will pose to you. Some will be content related, some will be about study skills or test strategies, and some will be more general. Since quizzes and tests will be held on Tuesdays, the responses will generally be due no later than noon on Friday of each week. The responses may be typed and turned in at class or brought to my office, OR emailed to me at the address on my syllabus, and must be at least 100 words long to be accepted. I will respond to each paper either by writing on them and handing them back or by replying to email.

[Note: The prompts were distributed individually early each week and posted on my website -- some samples are provided here as a group. Generally, there are 10 to 12 responses for a semester, at 4 or 5 points each, out of a 600-800 point total for the semester.]

1. Complete the attached Learning Style Assessment, and find the totals for each category. Determine which learning style is your dominant style. Then, read the brief description of each style on the back of this paper, and respond to the following:

What point value did you find for each category? Which learning style did you determine to be your dominant style? Does that information match what you believe about yourself, or did it surprise you? How do you think your particular learning style has helped you or hurt you in learning math, particularly this class?

2. Describe your experiences and attitudes about using a graphing calculator, and tell me which kind of calculator you are using.

OR

If you did not turn in a writing assignment last week, complete this thought:
"I did not turn in a writing assignment last week because...."

3. Imagine yourself taking our next exam, and write a paragraph describing a happy and successful exam experience. Give details about how you are feeling, what you are doing, the sights and sounds in the room, etc.
4. Give two examples of situations in which you have used, seen or can find the idea of probability OUTSIDE of this or other math courses. Be sure to explain the example thoroughly. [Magazines, newspapers, television, other courses, any of

these are possible resources.]

5. You have received a review sheet for the final exam for this class. Look through the problems on the review sheet and answer the following questions:
 - a. Which three topics (or types of problems) have been the most difficult for you this semester? How will you use this information in preparing for the final exam?
 - b. Which three topics (or types of problems) have been the least difficult for you this semester?

Replying to Journal Entries:

Please note that all student quotes are direct copies of the originals. No attempt has been made to correct spelling or grammar errors.

Writing Prompt A:

- How did you prepare for the first exam? If you prepared any differently than you have for previous math courses, explain what you did and why you think you chose that.
- Discuss your reaction to your performance on the first exam: tell whether it was what you expected, better, or worse and why. Also tell whether you are satisfied with the outcome.
- If you are not satisfied with the outcome, can you see patterns in your errors, or identify the cause of your poor performance? Consider at least 3 ways that are available to you to improve your performance on tests.
If you were satisfied with your performance, tell me at least 3 things that you chose to do that worked well for you.

Student 1:

Honestly, I did nothing to prepare for Tuesday's test. I completely forgot about it. I guess you could say I prepared for it without knowing by completing all my homework. I also did most of the practice problems and checked all my answers. If the answer was wrong, then I figured out why and then fixed it. On the first exam I did worse than what I expected. I didn't do terrible, but I didn't do as good as I would have liked. I got a 91% on my test. I went through it and realize what I did wrong. A pattern I found was with exponents. I didn't quite understand the negative and such. I forgot to label a problem with feet and didn't put undefined as another. Those were just stupid errors

that shouldn't have happened. None of them should have. But atleast I got a A. could have been worse. I could improve my test scores by skimming through the book before a test, writing down more class notes, double checking my test.

If I skimmed through the book before a test, it would remind me some rules I may be sktchy on remembering and put it fresh in my memory. If I write down more notes from class then I'll have yet another sourse tofall back on to remember and look up things I don't understand too well. If I were todouble check my test then it would probably eliminate the stupid errors such as forgetting the label answer. On the next unit I am willing to commit all of these ways to improve my next score. I reread things and double check my answers. I should bring my low A to a higher one.

Your Reply:

Student 2:

I didn't really prepare for the exam because I was pretty sure that I would do fine on it. I felt that I had already understood the problems. My reaction to the test was simply dissapointed because i have expevted better maybe there were things that i didn't explain good enough when I worked out some problems. I had mixed feelings anout my outcome because i expected better but I still passed.

I don't seem to see any patterns of errors other than not looking at the questions more closer or working out each problem in more detail.. I have no suggestions to improve my performance but to just try harder but I don't know how to try harder I thought I was trying herder before I got the test. Nothing has come to mind because I really thought I was trying my hardest. I reall don't know how i can inprove at this point. All I can do is hope I pull my grade p on this next unit.

Your Reply:

Student 3:

I prepared for the first exam by reviewing Chapters 1 and 2 in the text. My performance on the first exam is about what I expected, in the 85 to 90 range. I am reasonably satisfied with my performance on the exam. I received a grade of 89. Three things that worked for me were to review the chapters in the text, completing all the homework assignments, and attending all classes. If I maintain the same scenario throughout the course, I can probably keep a B average. One thing I've noticed is that the homework requires a solid 3-4 hour commitment. I sometimes do the homework at the last minute (night before it's due) when I am tired. This probably isn't the best way to absorb and retain the material. I will try to work on the homework and the advance reading prior to the last minute.

Your Reply:**Writing Prompt B:**

Write about what you perceive as different between a high school and a college environment. Below are some questions that might help you think out your response, but you need not address them specifically, nor are you limited to these.

- What did your teachers do for you in high school that you don't get in college?
- Did students study outside of class in high school, and do you think students study outside of class in college?
- Did students need to take notes in high school, and do you think students need to take notes in college?
- Are the people who succeed in high school the same ones who succeed in college?
- Did your fellow students help or hinder your learning in high school; is that any different in college?

Student 1:

High school was a very bad experience for me. I did really horrible in all of my classes. I was in low-level classes so even though I needed the most help there was an expectation that I would fail from the start. In college teachers are more concerned with the student and learning. In high school teachers are either burned out and don't care or focused on the disruptive students.

The material is very important I think that If I were to study the text book alone while in college I would do okay in my classes. In high school I couldn't tell you I never opened my text books to ever find out what was in them

I think that the success in college vs. high school is all relative. The kids that did good in high school are now taking challenging courses and there could be a slight decline in their GPA. If a student did mediocre in high school he/or she may be very successful in college because the learning environment is much more laid back. My case is similar to the latter. I had a 1.14 GPA in high school because there was so much emphasis on being cool or popular. My friends were all the same way they too just wanted to have fun. "When in Rome do as the Romans do". I wanted to chase girls not study. Now I have a 3.68 GPA, but I'm married, I don't drink, party, or blow off my assignments.

Your Reply:

Student 2:

I feel like college is a lot more laid back than high school was. In high school, there was soooooo much pressure about shooting as high as you possibly can and doing everything perfectly to look good on your college application ... It just was very overwhelming for me. They seemed to present standards that I didn't feel I could live up to.

In college, at least COMMUNITY COLLEGE, it seems like a lot of the pressure is alleviated. I am here voluntarily, paying for classes with my own money, so I feel as if I really have something invested in my education. If I don't study for tests and fail my exams, I've wasted my own money. But in college you can retake courses if necessary. Or you can postpone them. I have more control over my schedule in college than I did in high school.

Your Reply:**Student 3:**

Comparing high school and college is like comparing apples and oranges, they are two completely different things. College is all about time management, it's your time and if you want to be successful you better have your time planned out. In high school, teachers set your boundaries and reintegrate what the student should be doing and when the student should be doing it. In contrast, college students are the ones who make the decision of what needs to be done and when.

In high school teachers are constantly paying attention to every little thing you do, whereas in college they could care less. High school is more students oriented and college wants to make their money. Having said that, there are some professors in college who I think do genuinely care about the students succeeding but there are a lot of professors who just don't care. In high school I think teachers care more because they aren't getting paid for each class, so therefore the teaching material is just what they do. Where as in college, professors can teach the same material over again five times but it doesn't matter because they will keep getting paid for it. Some would say, it's a money making scheme!

A positive side to being in college is you have freedom. In high school you're just another kid, but in college you're an adult and for the most part are treated that way. In college you have to freedom to miss a class without permission, go to the bathroom without asking, wear what ever kind of clothing you want and if respectful you can speak your opinion.

Your Reply:

WRITING PROMPTS – Shaw

Each week you will be asked to write a brief response to a question or statement I will pose to you. Some are about mathematics; some are about learning in general. Please respond in complete sentences on separate paper, and attach this page as a cover sheet. The responses will be due no later than noon on Friday of each week. The responses may be written and turned in during class, brought to my office, or emailed to me at the address on the course syllabus. I will respond to each.

A. Prompt: Interpreting Directions

- Math directions are usually written in precise language. If you have ever been stuck on a test question because you did not understand what the directions meant, say so and describe how you usually react to this situation. If this has not happened to you, say so and say why you think you have managed to avoid this.
- Find an exercise from a recent homework assignment whose directions you found particularly confusing. (Maybe you even lost some points because you didn't understand the directions.) Copy those directions on your paper as they were worded in your textbook. Do not work the problems out.
- Now write better directions for that problem. Use words that you think would be clearer to a student like yourself.

B. Prompt: Getting the Right Answers vs. Understanding: Is there a difference?

- Sometimes students get the right answer and still don't understand the problem. Tell if you agree or disagree with this statement and explain why or why not. Please talk in general terms; then give one or more specific examples from the unit you are working on now in this course.
- Sometimes students do not get the right answer but understand the problem anyway. Tell if you agree or disagree with this statement and explain why or why not. Please talk in general terms, then give one or more specific examples from the unit you are working on now in this course.

C. Prompt: Considering Partial Credit

Some people believe that teachers should give partial credit for student work when figuring out the answers to test questions. Your instructor will have to decide what how to handle this when she grades examinations for this course. Now is your chance to be heard regarding this issue!

- Give some reasons or circumstances that present a good argument for when and why partial credit should be given.
- Give some reasons or circumstances that present a good argument for when and why partial credit should not be given.

D. Prompt: Deciding on a Next Course

You will soon need to make a decision regarding which math course to take after this semester. This Prompt is designed to help you select an appropriate course. Montgomery College offers [#] options that are discussed on the other side of this paper (What to Do After Taking Math 101). Consider carefully the career path you might undertake. It may be beneficial for you to talk with one of the math advisors or a counselor in general advising.

If you **do not** expect to pass this course, then answer the following Prompt with that in mind.

If you **do** pass this course, then you will need to select one of the courses listed on the reverse. Make sure you read the two paragraphs at the top of the paper AND the two paragraphs near the bottom, "Mathematics is very cumulative and if you skip a semester, you may find subsequent courses more difficult. It is recommended that ..."

Prompt: After reading the three paragraphs above, and the other side, please report what math course you expect to register for after Ma 101 and when you expect to take it. Then explain why you are selecting that course in particular.

E. Prompt: Letter to New Student

Write a paragraph or two to a student who will be starting this class next semester, telling him or her what needs to be done to be successful in this course. Please include more than one or two sentences!

In order to keep the letters anonymous, please do not write your name on the letter itself.

Critical Incident Questionnaire (CIQ)*

Please take a few minutes to respond to each of the questions below about this week's classes. Don't put your name on the form – your responses are anonymous. When you have finished writing, put the form on the desk by the door. At the start of next week's class I will be sharing the responses with the class. Thanks for taking the time to do this. What you write will help me design learning sessions that are more responsive to your concerns.

1. At what moment in class this week did you feel most engaged with what was happening?

2. At what moment in the class this week did you feel most distanced from what was happening?

3. What action that anyone (teacher or student) took in class this week did you find most affirming and helpful?

4. What action that anyone (teacher or student) took in class this week did you find most puzzling or confusing?

5. What about the class this week surprised you the most? (This could be something about your own reactions to what went on, or something that someone did, or anything else that concerns you.)

*Adapted from Brookfield, Stephen D., *Becoming a Critically Reflective Teacher*, San Francisco, CA: Jossey-Bass, John Wiley & Sons, 199

Questions ↓ w/Teacher Responses↓	Replies from Students ↓ ("✓" mark means that this reply was repeated)
<p>1. At what moment in the class this week did you feel most engaged with what was happening?</p> <p>It was a pleasure to observe so many students engaged and working together on the Algebra Review during class!</p> <p style="text-align: right;">Prof. Shaw</p>	<p>✓✓ going over answers to quiz and Algebra Review</p> <p>✓✓✓✓✓ group work</p> <p>✓✓✓✓ "yes" or "always" or "every moment"</p> <p>first day . second day.</p> <p>during hwk explanation</p> <p>✓✓✓ the quiz</p> <p>when we cut out the graphs and categorized them</p> <p>✓✓ scatter plotting exercise</p> <p>during lecture</p>
<p>2. At what moment in the class this week did you feel most distanced from what was happening?</p> <p>The first day of class is stressful for us all. I want to explain how the projects will work in the course and how the classes will run, but most students don't want to hear all that talk now.</p> <p style="text-align: right;">Prof. Shaw</p>	<p>✓✓ feeling lost with calculator work during Section 1.2</p> <p>✓✓✓✓✓✓✓✓ none</p> <p>this week was just review</p> <p>too much teacher talking</p> <p>work group</p> <p>✓✓ quiz. Today.</p> <p>✓✓✓ at the beginning, getting acquainted with everything</p> <p>getting a Study Group started</p> <p>when we were giving Video Reviews to be checked</p>
<p>3. What action that anyone (teacher or student) took in class this week did you find most affirming and helpful?</p> <p>I very much appreciated the students who actively contributed in the class activities and discussion, right from Day 1!</p> <p style="text-align: right;">Prof. Shaw</p>	<p>tchr explain common pitfalls, didn't assume everyone knew how</p> <p>✓✓✓ tchr answering questions about hwk problems or class work</p> <p>✓✓ tchr explain on board; showing how to work out examples</p> <p>✓✓✓✓✓✓✓ groups in class</p> <p>✓✓✓✓ no answer</p> <p>study groups</p> <p>quiz solution on Internet</p> <p>chance for extra credit with group study</p>
<p>4. What action that anyone (teacher or student) took in class this week did you find most puzzling or confusing?</p> <p>... that a few students assert they have never worked the kind of algebra problems that were on the Review. I worry that they will have a tough time in Ma 181.</p> <p style="text-align: right;">Prof. Shaw</p>	<p>✓✓✓✓✓✓✓✓✓✓✓✓ "none"</p> <p>graphing exercise</p> <p>when I couldn't do my homework</p> <p>✓✓✓ Grading Contracts.</p> <p>Projects: do we have to do all three to get 5%?</p> <p>the fact that groups were based on where we live</p> <p>directions on the quiz were a little confusing</p>
<p>5. What about the class this week surprised you the most? (this could be your own reactions to what went on, or something that someone did, or anything else that concerns you.)</p> <p>... that more students did not have questions regarding the 5% Projects.</p> <p style="text-align: right;">Prof. Shaw</p>	<p>✓✓✓✓✓✓✓ no answer</p> <p>amount of feedback requested by teacher</p> <p>✓✓✓✓✓✓ desk arrangement, working in groups</p> <p>the need to improve my algebra skills!</p> <p>the reminder that the quiz was Friday. Yikes!</p> <p>teacher didn't "teach" lessons on board</p> <p>amount of worksheets we get</p> <p>outside projects; choosing our own % breakdown for grade</p> <p>putting student answers on board for all to see</p>

Question	Replies
<p>1. At what moment in the class this week did you feel most engaged with what was happening? Observing how well the groups prepared for their Final Exam Review presentation <i>Prof. Shaw</i></p>	<p>✓✓✓✓ Wednesday's class - first final exam review bowl I kinda forgot how easy limits were way back when! ✓✓ Groups, so I could ask my classmates some questions</p>
<p>2. At what moment in the class this week did you feel most distanced from what was happening? During the "Essential Ingredients" work - I am worried that students do not grasp the logic behind them. <i>Prof. Shaw</i></p>	<p>I could not solve some problems in the Take Home quiz, even though I looked through the book for similar ones. The derivatives, including y, and the use of $\frac{dy}{dx}$ while working a derivative. Intermediate Value Theorem (understanding the ingredients) Toward the end of class, I kind of isolated myself from the class and got lost!!</p>
<p>3. What action that anyone (teacher or student) took in class this week did you find most affirming and helpful? When several students came by during the week, to sort out basic concepts of the course. It was good to see their efforts <i>Prof. Shaw</i></p>	<p>When we solve problems on the board and share with other classmates Step-by-step solving optimization problems Doing worksheets Giving more explanation on how to answer the Final Exam Review questions Extra points for final ✓✓✓ Review - the game This week was very helpful for us. When Group B explained the Related Rate problem on the board.</p>
<p>4. What action that anyone (teacher or student) took in class this week did you find most puzzling or confusing? ... that less than half the class is turning in the CIQs, even though 4-5 minutes class time is allowed for writing them. Should I have responded more often to their content? <i>Prof. Shaw</i></p>	<p>The inability of understanding word problems Fundamental Theorem of Calculus, Parts I & II Quiz: scoring out of 26?</p>
<p>5. What about the class this week surprised you the most? (this could be your own reactions to what went on, or something that someone did, or anything else that concerns you.) I have never had a class with such a high retention rate (from beginning to end of the semester). ☺ <i>Prof. Shaw</i></p>	<p>Can't believe it is the last day of class! The review quiz bowl is an interesting idea, flops though when $\frac{1}{2}$ your group is absent!</p>

Note: I left off the "no reply" or "none" replies this week.

Why Have Students Write about their Learning?

- Often a student knows more than he or she can explain verbally, so writing helps the student uncover more of what is known and express it freely, sometimes aiding retention. Because students have the opportunity to collect their thoughts on paper, the less vocal students still have a way to be “heard.”
- Writing about a subject can lead to a less restrictive view of the subject. Students may come to see the discipline and their success in that discipline as a process and a dialogue to which they can contribute.
- Because success in college depends on a student’s ability to respond to the challenges presented by new problems and new ideas, writing can be used to encourage critical thinking on a subject.
- “It is a quick and revealing way to ascertain the effects your actions are having on students and to discover the emotional highs and lows of their learning.” Regular written communication “provides [the teacher] with a running commentary on the emotional tenor of each class.” (Brookfield, *Becoming a Critically Reflective Teacher*)
- Reading student responses can help the reader (instructor) determine whether a student has begun to develop certain attributes:
 - *Intellectual engagement*
 - *Taking responsibility for own learning*
 - *Persevering when faced with adversity*
 - *Paying attention to detail*

In general, writing can:

- Help a student raise questions about new (or old) ideas
- Give a student a chance to reflect on what is known
- Provide an open avenue for communication
- Help address issues such as math anxiety
- Support the interdisciplinary approach to education.

Selected resources that Deb and Nancy have found helpful:

- Brookfield, Stephen D. *Becoming a Critically Reflective Teacher*, San Francisco, CA: Jossey-Bass, John Wiley & Sons, 1995.

Brookfield offers a personal guide to how faculty at any level and across all disciplines can employ critical reflection as a tool for continuous personal and professional development, as well as for improving delivery of a course.

- Downing, Skip. *On Course: Strategies for Success in College and in Life*, Fourth Edition, with Facilitator's Guide, Boston, MA: Houghton Mifflin, 2005.

While designed for English composition and student success/freshman seminar courses, this text is full of activities and strategies for teachers and learners, including a complete set of thirty journal prompts based on developing the "Eight Choices of Successful Students."

See also the extensive resources at the related website,
www.oncourseworkshop.com

- Felder, R.M. and R. Brent. "Navigating the Bumpy Road to Student-Centered Instruction." *College Teaching*, 44(2), 43-47 (1996).
An unabridged version of this paper can be found at
<http://www.ncsu.edu/felder-public/Papers/Resist.html>.

Felder and Brent discuss the nature and causes of student resistance to student-centered instructional methods, and techniques for avoiding or minimizing the resistance.

- *The Teaching Professor*. Madison, WI: Magna Publications, monthly online publication.

The Teaching Professor is a forum for discussion of innovative strategies, techniques and approaches that facilitate learning and in reflective analyses of educational issues of concern.

- Weimer, Mary Ellen. *Learner-Centered Teaching*. San Francisco, CA: Jossey-Bass, John Wiley & Sons, 2002.

Weimer suggests that five key changes must occur if higher education wishes to change to a focus on learner-centered education. The five key changes are in power, content, the role of the teacher, the responsibility for learning, and evaluation.

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THE DEVIL IN THE DARK: CASE STUDIES BRING BIOLOGY TO LIFE

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Abstract: Before critical thinking can begin, students need to be enticed by and engaged in the material. A case study approach is an excellent way to start this process. We will present case studies used in two different courses, environmental science and anatomy and physiology to illustrate how this approach can be adapted to different disciplines.

What's Needed for Active Learning?

-Information!

Sources of Information?

-Course Work

-Life Experience

How Does the Student Use the Information?

-Formulate New Ideas

-Construct Answers

Case Studies in General and Environmental Biology

General Biology:

- 100 level course
- Lecture Component

Environmental Science:

- 100 level course
- Lecture Component

Student population:

- Includes Majors (Requirement) and Non majors (General Education Requirement)
- Some may not have science background
- Traditional and Nontraditional Students
- Large Class Size (50 Students)

These are problems posed to students in the context of open book, group “quizzes.” Each was a problem that they received at the end of a unit.

Each week, a new problem was presented. As the semester progressed and more material was covered, the students were expected to handle each problem at a greater depth.

Case Study 1 – General Biology:

Consider the following scenario, modified from Star Trek’s episode 26, from March 9,



1967 (<http://www.ericweisstein.com/fun/startrek/TheDevilInTheDark.html>): Spock, McCoy, and Kirk beam down to confer with Chief Engineer Vanderberg. Spock notices a spherical silicon nodule, which Vanderberg describes as a geological oddity, on display in the Engineer's office. Spock notes that the nodule must have been moving at great speed in order to be capable of causing some of the deaths of the explorers which it caused. Tricorder readings taken of the creature show that it took in energy at the rate of 150 calories per hour and it seemed to consume rock as it tunneled through the planet's interior. Spock and Kirk speculate that the creature may be based on silicon instead of carbon. The tricorder also shows that the creature's body was made of regular components that seemed to be like cells.

The creature responded to the explorers by showing aggressive behavior, killing the humans it encountered on the planet. When Spock and Kirk corner this creature, Spock

mind-melds with it (makes telepathic contact with it), he finds out that it is a creature known as a Horta. He finds out that all the Hortas but this one have died off as a normal part of a 30,000 year reproductive cycle. Since there had been so few threats to the Hortas over many generations, the species changed to leave only one of its population alive to maintain the eggs of the next generation. Spock further explains that the Horta was only protecting the eggs which are being accidentally destroyed by the explorers, so that its kind can flourish again.

Can you see why Spock, McCoy and Kirk believed the Horta was a living organism? How does this Horta demonstrate the all the characteristics of life, except homeostasis?

Or. . . If you do not think Hortas are organisms, explain why it does not show these characteristics of life.

Case 2 – Environmental Science:

This case study was given during the topic involving ecosystems, after a discussion on exotic species.

Introduction of Exotic Species

The scenario for this problem was the colonization of Sigma-Seven, a class M planet. (Class M means much like earth in climate and geology.)

You are the biologist with a party of humans that is colonizing the Planet, Sigma-Seven, a class M planet. (Class M means much like earth in climate and geology.) As of yet, you have not completed the biological survey of the planet so you don't know exactly what already exists there. However, you must bring some plants and animals from home so that an agricultural system can be developed that will feed the new colony. It will be established in a grassland, year-round average temperature is 54°F, with an average low temperature of 28°F and an average high temperature of 86°F.

What five species will you consider bringing? Why? Do you expect any problems from introducing these exotic species on this planet?

Case 3 - Environmental Science:

This case study was presented after the students finished the topics on communities and niches, and while they were learning about freshwater ecosystems.

You discover an aquatic organism on Sigma Seven that is nothing like anything you know from earth. You will understand the organism better if you can describe its niche. Describe it – the physical factors that constrain and enable its existence, how it gets its energy, how it relates to other organisms. Finally draw and describe the organism; label features that are interesting to you in terms of how the organism fits its niche.

Case Studies Used in Anatomy And Physiology Lecture and Lab

Anatomy and Physiology I

- 200 level course
- First semester of a two semester sequence
- Lab component
- Content driven course

Student population

- Mainly pre-nursing, pre-allied health students
- Have some biology background
- Mix of traditional and non-traditional students
- Large class size (50 students)

Two case studies are given during the semester. They are assigned after the relevant material has been covered in class and are done outside of class time. Group work is encouraged but the product is an individually written paper. Case studies are designed so students must apply and extend concepts learned in class.

Lecture Case Study

An elderly woman was cooking a meal on a gas stove. She was wearing a long sleeved blouse which accidentally caught on fire. Luckily her teenage grandson was in his bedroom on the second floor of the house. He heard her shouts, ran downstairs and saw that her entire right upper limb and portions of her chest were engulfed in flames. He thought quickly, ran to get a towel, and managed to extinguish the flames. He then immediately called 911. The paramedics arrived shortly and transported the woman to the hospital.

During the emergency room examination it was noted that the entire anterior and posterior surfaces of her right upper limb, 50% of the anterior thorax, and 50% of the posterior thorax were involved. The burned areas appeared black and charred, with patches of white and yellow. No blistering was seen, and the skin was dry to touch. The patient reported no pain or sensation to the burned areas, but extreme pain and

blistering surrounding the charred and black regions. She exhibited labored breathing and made whistling sounds when breathing. The physician immediately put her on intravenous (IV) fluids, oxygen, treated the burned area with topical antibiotics and dressed the wounds.

1. What percentage of the total body surface has been burned? Show your calculations.
2. What type of burns has the woman received? Explain your answer.
3. List all of the layers of skin damaged for each type of burn listed in question #2.
4. Why does the patient report no pain or sensation in the burned areas, yet extreme pain in the surrounding areas?
5. Should this woman be admitted to a burn unit? Explain your answer.
6. Other than the obvious burned areas, what other type of burn injury might the physician be concerned with?
7. Why is it vital to the burn patient to be given fluids? Explain your answer by relating it to one of the functions of skin.
8. Why is the possibility of infection a major concern? Explain your answer by relating it to the functions of skin.
9. Why did the physician apply antibiotics topically rather than intravenously?
10. If the patient were a 1-year-old child what percentage of the total body surface would have been involved? How did you arrive at your answer?

Lab Case Study

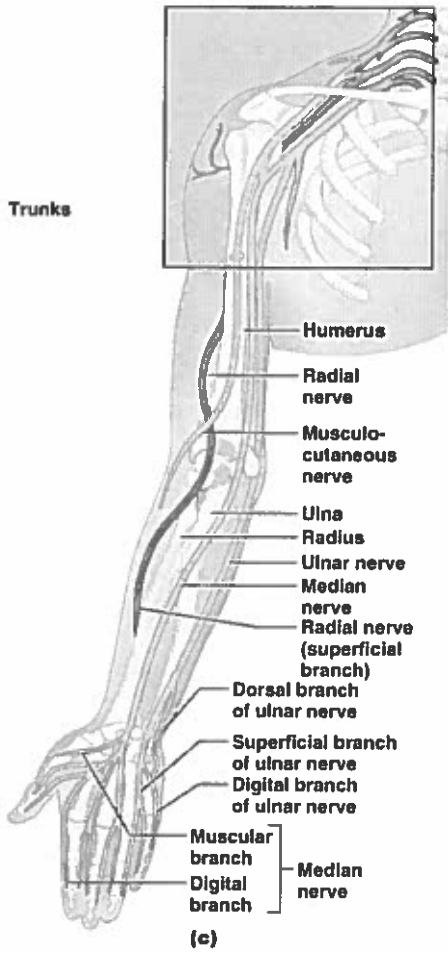
While playing ice hockey, John Orr was hit hard by a hockey stick in mid-shaft of his left humerus. He was taken to the emergency room where he presented with signs of tenderness, swelling, deformity, and abnormal movements of his left upper limb. The examination revealed an inability to extend the wrist and at the fingers at the metacarpophalangeal joint. He also has sensory deficits over the lower arm, posterior forearm, and the radial side of the dorsum of the hand. Measurement of the limb showed some shortening compared to the right limb. X-rays were ordered.

X-ray report: fracture mid shaft of the humerus. Note proximal fragment of the bone is abducted, distal fragment is displaced proximally.

1. What nerve may have been damaged as a result of the fracture? Justify your answer based on the anatomy of the humerus.
2. Explain the motor deficits John is experiencing. Be specific, what is the relationship between the nerve that is damaged and the motor deficits.

3. Would you expect to see a weakness in flexion at the elbow? Why or why not?
4. What is the basis for the sensory loss he is experiencing?
5. Why are the nerves not functioning properly?





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TEACHING CRITICAL THINKING WITH SIMULATED HOMICIDE INVESTIGATION AND MOCK TRIAL

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At Anne Arundel Community College, English 112, Composition and Introduction to Literature 2 gives students an opportunity to practice collecting, evaluating, and using evidence to draw valid conclusions. This course prompts them to explore their reactions to literary texts and human experiences described in them, to develop and refine their skills to communicate those reactions, and to build their confidence as a critical thinker and verbal communicator. In such a course, how can we arouse curiosity, provoke debate, cultivate critical thinking skills, and foster principles of personal ethics among students in our writing classes? One approach asks students to step into the shoes of detectives, witnesses, lawyers, jurors, and judges in cases drawn from literature.

Instructors may select an overarching theme to unify the reading and writing assignment for the course. One such theme that seems to work well is "Homicide and the Burden of Proof." Students focus on three main texts: Susan Glaspell's *Trifles* (1916), William Shakespeare's *Hamlet, Prince of Denmark* (1600), and Albert Camus' *The Stranger* (1942). The following paper will describe how each one of these texts stimulates students to consider complex interpretive and ethical questions during class discussions and activities as well as in their compositions.

Trifles

In *Trifles*, set in the U.S. at the turn of the 20th century, a woman is accused of first-degree criminal homicide. She is presumed to have killed her husband by ligature strangulation in their home while he was asleep. There are some signs that might indicate the woman was emotionally abused or neglected.

In this relatively simple play (It is written in our American English, has a very short script, minimal action, and five characters who appear on stage.) we meet five characters in all: three men and two women. George Henderson, the county attorney, is at the scene of the crime to collect any evidence that might convict Mrs. Wright of the charge against her: first-degree murder. Henry Peters, the sheriff, is present to supervise the investigation and to ensure that the crime scene is left intact and no evidence is tampered with. Lewis Hale, a "neighboring farmer" is there to explain Mrs. Wright's behavior the day Hale discovered Mr. Wright had "died of a rope around his neck."

Mrs. Peters is the sheriff's wife. Mrs. Hale is the wife of the neighboring farmer. They are at the scene of the crime to gather a few items that Mrs. Wright requested to be brought to her while she is in jail. Two important characters never appear on stage: Mr. Wright is dead upstairs in the bedroom and Mrs. Wright is in the county jail.

The men regard the activities of the women and the small details they pay attention to as insignificant and irrelevant. The great irony of the play, however, is that these so called "trifles" are the key to understanding what happened at the Wright family farm leading up to Mr. Wright's untimely death. The women notice a half-wiped table, broken jars of preserves, a broken birdcage, and an unfinished quilt, items that do indeed seem unimportant. However, they also uncover a dead bird wrapped in silk and hidden within a decorative box, and uneven stitching on the quilt's edge. These, the women conclude, are significant enough, perhaps, to establish a motive and incriminate Mrs. Wright, and so they conceal the evidence from the authorities.

Most readers of the play *Trifles* enjoy debating what all of this evidence means. It becomes a mystery game. Some students will accept the interpretation Mrs. Peters and Mrs. Hale give to the evidence they find: that Mrs. Wright did kill Mr. Wright but does not deserve to be convicted of murder because her actions were justified. Others will come to believe that Mrs. Wright is not the murderer everyone seems to believe she is; after all she never confesses. Still others might become more sympathetic to Mr. Wright as the victim of a cold-blooded murder, and perhaps even the other men in the play, since they are on the side of the law and seem to represent the American justice system.

In any case, this play is designed leads the reader to become more conscious of her or his own reading and interpretive habits. It reveals the ways people base their interpretation of reality on a set of assumptions and expectations that extend far beyond the simple shards of evidence in front of them. We are led to imagine for ourselves what series of events led to the death of Mr. Wright. What we know is deduced from the evidence at the scene of the crime and heavily influenced by the interpretations developed by a set of other characters. We begin to sense that we as the audience of this drama have been drawn into the process of "reading" the signs too. And just as the interpretations Mrs. Hale and Mrs. Peters develop are rooted in their own personal experiences, assumptions, and values, we become aware that our interpretations also rest on experiences, assumptions and values that we bring to our own readings. We have been invited by Glaspell to participate in a complex process of evidence collection, analysis and interpretation, and in this way our own reading process is brought to light. Students are encouraged to keep an eye not only on what happens on stage, but also on their own assumptions about men and women, marriage, and human nature that inform the way they read the clues in *Trifles*.

A discussion of *Trifles* almost inevitably raises questions about valid interpretation. How can you distinguish a valid interpretation from an interpretation that is invalid? Are there degrees of validity? In other words, what constitutes effective analysis and legitimate interpretation? Students may already know that to arrive at a valid analysis and interpretation of a text, they must read and reread the text carefully, develop a complete, complex, and in-depth understanding of the text, and avoid adding, omitting, or changing the text. In discussing such a short play, students begin to see the value of close reading and they also begin to develop and trust their ability to interpret literature. The play itself motivates students to acknowledge alternative readings of the text but arrive at their own conclusion regarding the meaning of what they observe. When each student presents his or her analysis and interpretation, s/he should be encouraged to argue and defend her or his own interpretation with ample evidence from the text and compelling reasoning.

A logical application of the critical thinking skills students develop during class discussion of *Trifles* is a writing assignment that asks students to assume the identity of a detective and to create a crime scene investigation report. Each student is responsible for documenting, analyzing, and interpreting the physical (material, tangible) evidence found at the crime scene depicted in the play *Trifles*. In other words, each student must (1) accurately identify each piece of physical evidence, (2) make close observations about each piece of physical evidence, (3) draw logical conclusions about the significance of each piece of physical evidence, and (4) propose a coherent and plausible theory that explains what happened at the Wright family farm leading to the death of John Wright. Although students are encouraged to entertain several different interpretations of the evidence as they discuss the play, each essay must support only one interpretation and arrive at only one conclusion. Students must struggle to focus on the most probable sequence of events that led to the death of John Wright and prove that one reasonable and probable explanation of what happened leading up to the death of John Wright.

Hamlet

Whereas in the discussion of *Trifles* the main question had been how can we interpret the physical evidence to arrive at reasonable conclusions about what happened at the Wright family farm leading to the death of John Wright, in the discussion about *Hamlet*, the main questions become, given all of this conflicting testimony from a set of questionable characters, whom should we trust and why?

The plot of William Shakespeare's *Hamlet, Prince of Denmark*, is so well known that a summary seems unnecessary here. It involves all of the following kinds of homicide:

death in battle, death in sport, fratricide, regicide, public execution, poisoning, stabbing, accidental murder of a government spy, and perhaps abortion. It required readers to distinguish each complex character from the next, to analyze a play that uses poetic and archaic diction, and follow an intricate plot about lies and betrayals. At the heart of this play is the struggle to distinguish artifice from reality, acting from authenticity, fabrication from truth, delusion from clarity, and deception from confession.

In almost every scene of the play, students encounter something that requires them to assess the credibility of a character. For example, at the close of Act IV, Gertrude enters to announce Ophelia is “drown’d.” Because Ophelia’s death happens off stage scholars often debate whether textual evidence supports the idea that Ophelia committed suicide, died accidentally, or was murdered. Scholars such as Stephen Ratcliffe argue persuasively that the language Gertrude uses here may in fact suggest that Gertrude is responsible for murdering Ophelia while others suggest the imagery and symbolic flowers in Gertrude’s narrative point to Ophelia overdosing during an attempted abortion. Keep in mind that Gertrude is narrating a scene to Claudius (who would benefit from Ophelia being silenced) and Laertes (whom the king is attempting to win to his favor). Of course a valid assessment of Gertrude’s credibility would depend not only on this scene but also on a careful examination of her earlier actions, words, and motives.

In a fictional world where everyone seems to be playing a role according to some hidden agenda, we naturally question each character’s motives and integrity; and since there are degrees of credibility, we measure how trustworthy each character is against the other. It is useful to offer students a set of criteria for assessing credibility so that they avoid flat analyses of the characters in the play. The following criteria seem to be useful:

- *Authenticity*: The character has an unambiguous and legitimate identity.
- *Competency*: The character possesses sufficient knowledge and experience of the subject.
- *Authority*: The character demonstrates expert command of her/his subject.
- *Reputation*: The character is in good standing, prominence, and status.
- *Coverage*: The character of the source’s knowledge is of adequate scope, breadth, and depth.
- *Accuracy*: The character is precise, truthful, and uncompromised by exaggeration, insobriety, mental instability, or flawed sensory perception or memory.
- *Integrity*: The character demonstrates consistency and strength of character.
- *Accessibility*: The character cooperative, articulate, and intelligible.

- *Objectivity*: The character is informative, just, unbiased and free of ulterior motives, mere impressions, and unsupported opinions.
- *Responsibility*: The character reflects logical reasoning, accountability, and self-control.
- *Presentation*: The character has an appearance, expression, and delivery that inspire trust.

Credibility is complex and students should be reminded that they would arrive at a very narrow view of someone if they used only one or even two of the above criteria. For instance, a character may in fact have an excellent reputation and yet have no integrity. So, it is wise to employ several or all of the above criteria in your assessment. Also, while it may be true that some people judge credibility by other criteria – age, race, sex, class, ethnicity, etc. – the most fair and logical way to determine if someone is believable and trustworthy does not rely on stereotypes or generalizations of any kind, but relies instead on keen observations about each individual person’s motives, words, and actions in many different situations.

Students often work best in small groups during this complicated discussion about Hamlet and credibility. Pointing to specific passages in the play, each work group might have the responsibility of reporting to the class any observations they have made about how the actions, intentions, words, and reputations of the character they are assigned enhance or diminish the credibility of that character. In this way, students take turns presenting their findings to the class and managing class discussion. The following Teams seem balanced, since some of the characters are not present for a number of scenes in the play while others are in almost every scene:

Team A -- Hamlet

Team B -- Claudius

Team C – Gertrude and the Ghost

Team D – Polonius and Laertes

Team E -- Ophelia and Horatio

The writing assignment that compliments this discussion asks students to write an essay that compares three characters according to their levels of credibility and prove that their assessment of credibility rests on valid reasoning and compelling evidence in the text of the play. Students are encouraged to not make assertions that can be easily challenged and discredited by other evidence in the play and to not simply summarize what is said and done by each character. Instead, they are prompted to analyze the play closely and read each character’s complete set of actions and words critically, to discover falsehoods, encryptions, disguises, double entendre, limitations,

contradictions, deceptions, errors, and omissions as well as moments of honesty, sincerity, authenticity, responsibility, consistency, and competency. Their job is to reveal the *true nature* of each character and to accurately represent his or her relative credibility when compared to several other characters. It should be abundantly clear to the reader how characters are *ranked* according to their credibility and why. Students are asked to prove that what they are saying is true by presenting compelling evidence from the text of the play in the form of quotations.

The Stranger

After a lengthy discussion of *Trifles* and *Hamlet*, students express that they feel much more confident in their ability to respond to literary texts in creative ways that actually ask them to apply their own personal standards. They are prepared to apply what they have learned about evidence analysis and character assessment to the actions and intentions of a challenging character such as Meursault in Albert Camus' *The Stranger*. The novel can be used as a case study that will ultimately ask students to come to verdict about the protagonists' actions and intentions.

The plot of *The Stranger*, divided into two parts, is relatively simple. After Monsieur Meursault, a shipping clerk with no ambition or aspiration for his future, receives news of his mother's death, he travels a short distance to the retirement home where she had been living for three years, the last two of which passed without visitation from her son. Meursault sits in vigil at her wake, refuses to view her body, attends her funeral, and then resumes his daily life as if nothing has changed. He forges a romantic/erotic attachment with an ex-coworker named Marie Cardona, a friendship of sorts with Raymond Sintes, his neighbor who abuses his girlfriend, and a tolerable acquaintance with Salamano, an old mangy neighbor who abuses his pet dog. In each of these relationships, Meursault demonstrates apathy, disinterest, and a high level of tolerance for racism, sexism, and violence. He also participates in a scheme that lures Raymond's "Moorish" girlfriend back to his apartment so that he can beat her again, and he later serves as a character witness in Raymond's defense when he is apprehended for assault. Justice, it would seem, is not served in this instance.

When Meursault, Marie, and Raymond travel to visit Raymond's friend Mason at his house near the beach, several Arab men, one of whom is the brother of Raymond's ex-girlfriend, follow them. Raymond comes to blows with the Arab man on the beach, is cut by the man's knife, and retreats to Mason's house to bandage his wound. In an attempt to escape the sound of women crying and the heat of the sun, Meursault returns to the beach, seeking a cool spring behind a large rock. When he approaches the rock, he sees one of the Arab men. As he approaches, the man wields a knife and Meursault is blinded by the glaring sunlight reflected by the blade. Sweat and tears fill

his eyes and cause his vision to blur. Meursault kills the Arab man with one shot, but fires four more times into the motionless corpse.

Meursault, a French Algerian, is accused of murdering an Arab man in cold blood on the beach a short distance from Algiers. After a year-long inquisition and trial, he is found guilty and sentenced by three judges of the high court to public execution by guillotine. But is this civil court the locus of justice for Meursault, or does he feel a greater judgment from the populous, who he hopes will attend his execution, memories of his father, who was physically ill with disgust after watching the death of a criminal, the eyes of his mother's neighbors who seem to be the first jury in the novel, or does justice originate within himself? Students will most likely require some explanation of Camus' atheistic ideal of the absurd hero and Meursault's refusal to seek punishment or reward from a divine power beyond himself; the question remains, however: where is justice to be found?

A mid-century Algerian justice system will undoubtedly seem alien to students in the Maryland higher education system, but they can understand that in a contemporary context, Meursault would be charged with 1st Degree Criminal Homicide (Murder). According to the Maryland State Criminal Code § 2-201, a murder is in the first degree if it is a deliberate, premeditated, and willful killing. A deliberate killing is committed with sound mind and an awareness or consciousness of one's actions. A premeditated killing is committed with aforethought or planning. A willful killing is committed with the malicious intent to kill.

Students will need to notice that the definition hinges on an identification of intention rather than a classification of action or method. That is to say, the facts are Meursault pulled the trigger of the gun that killed a man; what is open to debate is why he did it. During a mock trial and in a major writing assignment, students must determine whether Meursault's intentions define his actions as first-degree murder or something else altogether. And, since in the state of Maryland, the penalty for murder in the first degree might be death or imprisonment for life, they will probably want to discuss the penalty that should be attached to Meursault's actions.

Asking students to conduct a mock trial, during which Meursault is brought up on charges on murder in the first degree, allows students to participate in a simulated justice system and to apply what they have learned from earlier analysis of *Trifles* and *Hamlet*. Students will play the roles of defendant (Meursault), prosecution, defense, judge, jury, and clerk. The Maryland Circuit Court offers a script for mock trials at www.courts.state.md.us/mocktrial/script-final.doc that can be adapted for educational purposes. During the mock trial, the judge reads the indictment and instructs the jury.

The Prosecution and Defense take turns presenting opening statements. Then Meursault is called to testify (using the language in the novel as his deposition). The Prosecution and Defense take turns questioning and cross-examining the witness. The jury deliberates and then comes to a verdict. The level of formality for a mock trial in a classroom will vary and I encourage you to allow your students to direct themselves as much as they would like to, as long as they keep to the scripts of the trial.

Finally, individually each student determines the nature of Meursault's intentions at the moment when he kills the man on the beach. In a composition framed as a set of closing remarks to the trial, each student assumes the identity of either the Prosecution or the Defense and argues that Meursault is either *guilty* or *not guilty* of the charge of *1st Degree Murder*. They use the text of the novel as Meursault's deposition, a sworn statement written by the narrator/protagonist and offered as a complete and accurate account of events as he recollects them. Students may find the complete Annotated Criminal Code of Maryland in the Criminal Law Article at http://www.dsd.state.md.us/comar/Annot_Code_Idx/CriminalLaw.htm and a useful glossary of legal terms at Law.com's <http://dictionary.law.com/>.

Conclusions

These approaches to reading literature are creative and innovative; students respond to them because they can bring their own personal standards and their own critical thinking skills to bear during discussions and in their writing assignments. The outcomes of such an approach to literary analysis are very positive. Students gain confidence in their ability to respond to literary texts and apply their personal standards to assess actions, intentions, and characters.

Evolving Your Pedagogy from “Chalk-and-Talk” to “Click-and-Think” with Interactive Excel Spreadsheets

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Wouldn't it be great to have a tool that allows your students to discover concepts, is easy to create and modify, does not cost much, and is readily available? Well like chalk in the classroom, spreadsheets, especially Excel on a computer, are that tool. This article explores the use of interactive Excel spreadsheets to get your classroom to be more learner-centered, guided-inquiry based, and technologically-enhanced with an off-the-shelf, work-place common piece of software.

What is an interactive spreadsheet?

In an interactive spreadsheet when a change in some input variable occurs, the spreadsheet responds by simply recalculating quantities and adjusting a graphical display. The graphical and numerical visualizations are dynamic. The manipulatable variable can be changed by typing a new value in a cell or it can be linked to a number of features (the interactive “bells and whistles”) that are available in Excel. All of this can be done by computational means (the use of formulas) and does not require any programming skills. We are going to produce Javaless applet-like objects or Excelets. To get started with interactive spreadsheets, it is assumed that readers are knowledgeable of the use of Excel. This means you can transform data in a column (use formulas), graph it, and do regressions (trendlines as they are referred to in Excel). In simple terms, you can determine a mathematical relationship or model from data. If you need to gain this experience, see [Using Excel for Handling, Graphing, and Analysis of Scientific Data: A Resource for Science and Mathematics Students](#) to get started. Modeling data is a very important science process that mathematics educators have highly endorsed. However just examine most college science textbooks and you will see that it has been slow to be recognized by science educators. The mathematical modeling of data naturally leads into running and investigating simulations, which now is the pedagogical power of interactive spreadsheets.

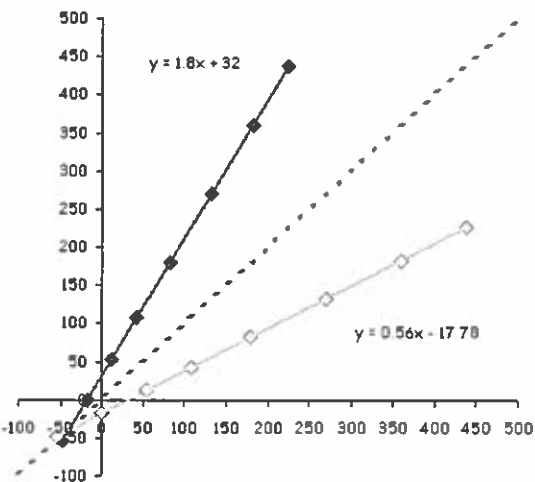
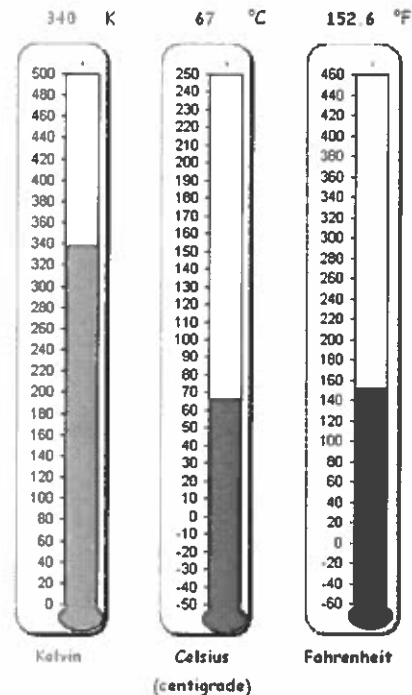
Exploring the Temperature Scales via an Excelet

This is an Excelet that allows students to discover the conversions among the Kelvin, Celsius, and Fahrenheit temperature scales using a graphical display and regression equations ([Temperature Scales Excelet](#) and [pdf handout](#)). Students do not need to know anything about linear regression. They will adjust a slider (or scroll bar as it is called in Excel) to vary the temperatures and collect some data. The data is displayed at

the top of the bar graphs, as shown on the figure to the right. These bar graphs have their y-axis scales set to cross at the maximum; hence, the white upper bar is the graph and moves down over a colored background as the minimum is lowered. This allows negative temperature values. The data are placed in a table that will automatically generate graphs and the equations of the linear relationships. Students must then come up with the conversion relationships from the generic mathematical equations (remove "x" and "y" and add new symbols for the variables studied).

Temperature Scales

225 kelvins 500
 < 340 >
 Adjust the slider or type a value in the yellow cell.
 How do the degree sizes compare?
 For 1 kelvin, how much does the Celsius change?
 answer: 1 correct
 For 1 kelvin, how much does the Fahrenheit change?
 answer: 1.8 correct



So the student generates the relationship to convert Celsius to Kelvin and then is asked to derive the Kelvin to Celsius. This gets into the concept of inverse functions (see graph below), which is explored via graphs and equations as well.

Inverse functions are reflections about the $y = x$ line (orange dashed line). This makes a nice connection between the mathematics and the science.

As a follow-up evaluation of this Excel, students are asked to derive the similar conversion relationships for the Rankine temperature scale with Kelvin, Celsius, and Fahrenheit scales. This also makes them use Excel for handling, graphing, and analyzing the data.

Students can also "invent their own temperature scale" by selecting two reference point values for the boiling and freezing points of water. Then they explore the meaning of the slope (degree size) and intercept (difference in freezing points) for the conversion equation from the Celsius scale to their scale.

Tapping the Pedagogical Power of Interactive Spreadsheets

Spreadsheets provide a great way to analyze and graph data, and then develop a mathematical model, all-the-while reinforcing the rule of four, examining the numerical, symbolic, graphical, and verbal representations, advocated by mathematics educators. Interactive

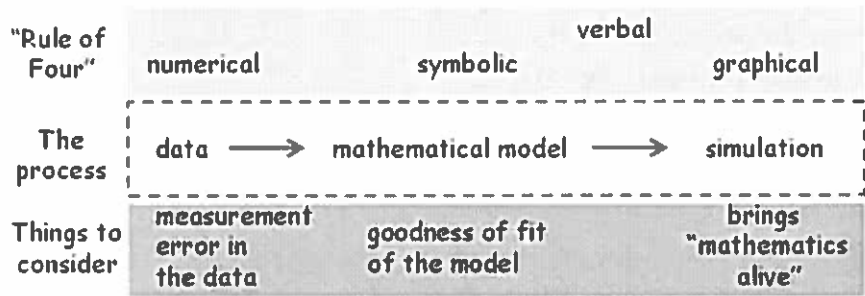
spreadsheets bring the mathematics alive.

This is the real-world of scientific

investigation. In the

course of an investigation,

measurement error and goodness of fit for regression models need to be considered. So now, how do you get into all of this? Here are a set of interactive Excel spreadsheets or Excelets that will get your students into mathematical modeling with a minimum of effort.



Concept	Excelet	Activity	Comments
Your first model with experimental data	Cookies	Handout	"Just add data" Excelet with two simple simulations
Understanding linear regression and goodness of fit	Regression	--	Learn all you need to understand how linear regression works in 5 minutes
Difference between interpolation and extrapolation	I & E	--	Distinguish the two terms and the dangers of a linear model breaking down
Scatter in data and outliers [learn more...]	Scatter	Handout	Develop an understanding of r-squared, residuals, and the effects of outliers
Explore types of errors in data [learn more...]	Error type	Handout	Investigate how random and systematic error influence data, and curvature

The Excelets listed in the table above will introduce your students to: building a linear model from experimental data by measuring the height of stacked sandwich cookies; investigating the meaning of the slope of the model; uncovering how variation in cookie thickness influences the data; and making some predictions with the model. Students can get a quick introduction to linear regression, measures of goodness of fit, and some ways to determine if the model is non-linear. Through numerical experimentation and "what if" scenarios, students experience activities that are guided-inquiry based, as the

mode of questioning is what will drive your students through the learning process and concept discovery.

Now let's change the direction of the science process. We can use an Excelet which is based on a mathematical relationship to discover that relationship. Your students do not know this. This is scientifically backwards, but it allows students to discover the correct relationship. Then we build random and systematic error into the Excelet to get the real-world experience of how the data would behave. For an interactive Excel spreadsheet investigation of radioactive decay and associated measurement error, see [Exploring Radioactive Decay in Excel: An Interactive Visual Thinking Tool](#).

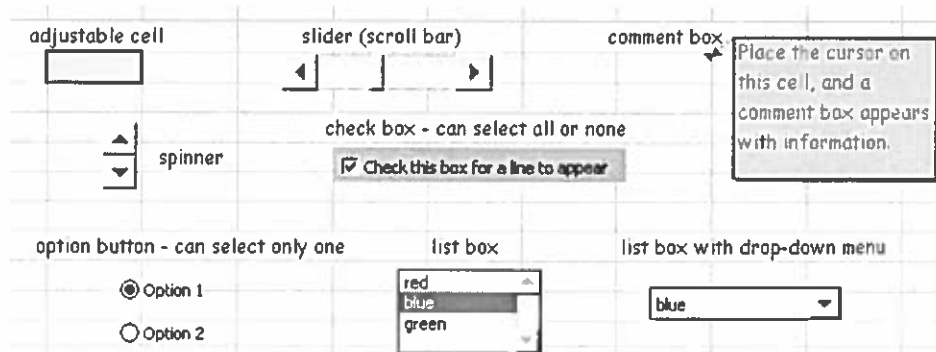
The ultimate use of Excelets is to extend a discovery-based laboratory where data is collected and analyzed. This provides the opportunity to explore multiple variables and address why we hold certain variables constant during experiments. The table below gives two examples of discovery-based laboratories that are enhanced with Excelets that include examining error. More Excelets can be found at the [Chemical Excelets](#) page.

Laboratory activities	Excelets and accompanying handouts	
The Behavior of Gases	The Ideal Gas Law (handout)	P-V II – The Tubing Error
More Lights, Color, Absorption!	Beer's Law Simulator (handout)	Beer's Law Simulator II: Exploring Errors (handout)

Constructing Your Own Excelets

The wherewithal for producing Excelets can be found at the [Developer's Guide to Excelets](#), which includes an Excel tutorial, illustrated instructions with numerous screenshots, and

many more examples. Take the [interactive features tour](#) to see what features are available in Excel to add interactivity and dynamic change to a spreadsheet.



The interactive bells-and-whistles are illustrated in the graphic above. All of these are done by computations or formulas in the spreadsheets with a number of clever tricks such as using logical statements, autofilters, or look-up tables. For the Excelets used here always look under the graphs on spreadsheets, since many items are explained here (just don't tell my students). An Excelet can be as simple as a spreadsheet set up to graph when the data is added, a calculation aid when data is added, or a simulation that looks at the effects of changing a number of variables. Topics can range from fractions for elementary students to quantum mechanics for upper level undergraduate/graduate students. Instructors with a little Excel experience can easily be developing Excelets!

Excelets as a Learning Tool

As mentioned previously, there are a variety of ways to use Excelets in your classroom. They may be used to support exploring a topic in a discussion. Here you can propose questions, have students make predictions, and then show them the outcome. Learner-centered activities can be developed for both in-class done in a computer lab or out-of-class assignments to explore a topic.

Student survey data (general chemistry I and II) for the ease of overall use of an Excelet as an out-of-class project are shown in the table below. The cookies project as an introduction for first semester students is less demanding than the end-of-semester project on radioactive decay for second semester students. The radioactive decay project introduces new concepts not covered in class; hence, students must develop an understanding of these concepts on their own from the project.

Project - Excelet	Percent that had no difficulty	Semester (number of students)
<u>Investigating the Height of a Stack of Cookies</u>	89%	Fall 2006 (19)
<u>Exploring Radioactive Decay Kinetics</u>	74%	Spring 2005 (23)
	73%	Fall 2005 (30)
	55%	Spring 2006 (22)
	63%	Fall 2006 (32)

For the Exploring Radioactive Decay Kinetics project, students were asked "Do you think this activity helped you understand the concepts involved with radioactive decay?" and the results are given below. Students were also assessed about their understanding by a question similar to the project on the final exam. The percent gain (improvement) or break-even (same score) compares their final exam score to their

project score. The gain appears to increase with the positive student response to understanding.

Semester (number of students)	Positive student response	Percent gain or break-even
Spring 2005 (23)	65%	48%
Fall 2005 (30)	57%	29%
Spring 2006 (22)	82%	52%
Fall 2006 (32)	53%	29%

Students were asked whether they preferred doing the activity or listening to the same content via lecture, with results are given below. Not surprisingly given the choice, students prefer to be passive learners. As instructors, we need to insist on and provide activities that engage students and force them to be active learners.

Semester (number of students)	Activity or Click-and-Think	Lecture or Chalk-and-Talk	Both
Spring 2005 (23)	30%	57%	13%
Fall 2005 (30)	43%	50%	7%
Spring 2006 (22)	41%	59%	0%
Fall 2006 (32)	41%	47%	13%

To start up the use of Excelets, demonstrating the use of one in class is highly recommended. Show students how to use the various features, so students do not need a vast amount of Excel experience to get started. Developing the activities around the use of an Excelets should require asking students to adjust variables in a systematic way over the full range as this is numerical experimentation; and it should propose the "what if" scenarios. Through the "what if" questions you can explore direct and inverse relationships and the sensitivity of systems to changes in variables. We can examine the effects of random and systematic errors as well. The amount of higher-order thinking questions (interpretation, analysis, and synthesis) and science processes (hypotheses, predictions, conclusions) that can be covered is limitless. Algebraic thinking is also supported through multiple representations and examining patterns and variables. All-the-while, you have converted your classroom to a very active learning environment and employed a powerful visualization tool. Your classical lecture has now evolved into a more discussion-based format with students discovering concepts using technology as well. Student engagement via out-of-class projects or follow-up activities in the laboratory is increased considerably. These also provide another great way to add interactivity to instruction in online classes.

Some Final Thoughts

With the use of off-the-shelf software such as Excel, a very powerful visualization tool can be created to support mathematics and science instruction or any area that involves some data. Students can explore and discover concepts through the mode of questioning to facilitate their journey. The use of Excelets creates an engaging pedagogy for students and supports national standards in mathematics, science, and technology as given in the table below.

Organization	Standards
American Mathematical Association of Two-Year colleges	<u>Beyond Crossroads</u>
International Society of Technology Educators	<u>National Educational Technology Standards (NETS)</u>
Mathematical Association of America	<u>Curriculum Renewal Across the First Two Years</u>
National Academy of Sciences	<u>National Sciences Education Standards</u>
National Council of Teachers of Mathematics	<u>Principles and Standards of School Mathematics</u>
National Science Teachers Association	<u>College Pathways to the Science Education Standards</u>

Spreadsheets offer a tool for data analysis, mathematical modeling, and building simulations, all-the-while using a work-place common piece of software. Excelets address the visual (various types of graphs, use of conditional formatting) and kinesthetic (interactive features) learning styles. With the mode of questioning, they drive students toward deeper learning. For further exploration and development of Excelets, see the author's webpage at <http://academic.pgcc.edu/~ssinex/excelets>. An extensive list of Excel resources for mathematics and the sciences is also available.

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