Jigsaw on Teaching Methods

Method #1:
Pre-Class Readings and Homework (Look-Ahead Homework)

- Reading and homework assignments are due prior to in-class discussion of material
- Classroom interactions can focus on concepts
- Encourages self-directed learning
- Same amount of work for students, but front-loaded
- Improved feedback time
- Limitation: requires readings that students can understand on their own, *e.g.*, a good textbook

Department subject Unified Engineering, and was described in detail by Prof. Steve Hall in the previous Aero/Astro review.

Weekly (graded) homeworks on material given prior to being discussed in class. In orderto increase the effectiveness of the concept-based lecturing, students need to have engaged the material prior to class. Without this prior engagement, students may not have sufficient background in the material to even understand the conceptual questions being asked. Traditionally, engineering courses almost exclusively assign homework after the concepts have been presented in class. However, to improve student preparation, I give homework assignments (with appropriate reading) on material prior to in-class discussion. These homeworks are essentially the same difficulty of homework I would have given after a set of lectures in the traditional pedagogy. With this preparation, the classroom becomes an interactive environment where students are ready to discuss the conceptual difficulties they have faced and have begun to develop a common language to have this discussion.

A semester long, team-based analysis and design of an aircraft. Typically, aerodynamics and other advanced engineering topics are taught with a significant focus on theory but little opportunity to apply theory especially to problems that approach the complexity faced in the design of modern aircraft. As a result, students perceive they are learning material 'just-incase' they may need it later in their careers. In the project-based approach used in 16.100, the knowledge is immediately being applied. Furthermore, the use of a semester-long project provides a context for learning the technical fundamentals as proposed in our Department's Conceive-Design-Implement-Operate (CDIO) initiative. Over the past four years, two design projects have been developed: one based on a military fighter aircraft (in collaboration with Michael Love of Lockheed Martin) and another on a blended-wing body commercial transport aircraft (in collaboration with Bob Liebeck of The Boeing Company and a Professor of the Practice in our Department). Both of these projects have an initial modeling phase in which student teams develop and validate aerodynamic models for a baseline

A student project team discusses the aerodynamic analysis of a blended-wing body aircraft with Prof. Darmofal during a weekly project work session.

The new pedagogy, in its final form, is consistently rated as highly effective. The past three years (Fall 2001 – 2003), the pedagogy as described above has remained nearly the same with only minor adjustments. As shown in Table 1, the mean student ratings of the effectiveness of the pedagogy are all between effective to very effective.

Challenging pre-class homework increases the effectiveness of lecture. In the Fall 2000 semester, while the pedagogy was as described above, the pre-class homeworks were designed to encourage reading but did not require significant engagement of the material. As a result, the students were not sufficiently prepared for in-class active learning and found the overall approach to be less effective. In fact, the student feedback from the Fall 2000 course evaluations led directly to the decision to increase the difficulty of the homeworks. The post 2000 data shows a statistically-significant increase in the mean effectiveness of not only the homework but also the lectures compared to Fall 2000 (see Table 1).

A learning transition occurs over the length of the semester. The open-response questions show that students are often initially hesitant about pre-class homework, but by the end of the semester they recognize the benefits of this technique. Some of the comments include:

- *I was initially opposed to the idea that I had to do reading & homework before we ever covered the subjects. Once I transitioned I realized that it made learning so much easier!!*
- *I was skeptical at first of new techniques like [concept questions], homework on material that hasn't been learned in lecture. In the end, it worked out very well. This has been a course where I really felt like I got my money's worth.*
- *Prof. Darmofal forces you to learn the subject material by assigning homework that he has not covered in lecture, therefore I have to force myself to read the text and go to office hours. When he does go over in lecture after the Pset is due, I did absorb the material much better.*
- *Doing homework before the lectures is good… makes actual learning in lectures possible.*

The comments also reinforce the link between the pre-class homework and the effectiveness of the lectures.

The effective implementation of the team project is difficult. One of the most challenging aspects of the new pedagogy has been the implementation of the team project. In the first place, the project has multiple facets (in particular the wind tunnel experiments and the computational simulations) that must be successfully managed. Furthermore, keeping ten or more teams of four students functioning effectively can be highly time-consuming for both the faculty and the students. The open-response questions for the past three years clearly show both the benefits as well as the difficulties of the team project. During this time, 31 positive comments were made about the project with only 2 negative comments; however, 29 students suggested the need to improve the implementation.

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Method #2:
Case Study

- Story of a real engineering experience, organization, or event
- Students face problems that are difficult for students to experience first hand, because of danger, limited access, limited equipment, etc.
- Problems that may span months or years can be addressed (and solved) in a short time
- Students have opportunities to exchange ideas with others about real engineering problems
- Limitation: finding “good” cases in specific engineering disciplines

Case Study Approach to Learning

San José State University

What is a case study?

1. A case study is a "real-world" example of the content or steps in the instructional systems design approach, it connects theory to practice.
2. Case studies are practical examples or uses of information that you have already learned in other courses.

How do you analyze a case?

1. Begin by understanding the context in which the case is being analyzed or discussed. What is the topic being discussed this week? How does this case relate to the topic?
2. Read the case. For the first reading, get the "big picture" the characters, the setting, and the context.

Next ...

❸ Read the case again - actively take notes or underline passages.

❹ Analyze the case. Identify the key issues, consider the perspectives of the key players, generate possible solutions, think about consequences of various paths of action, weight the advantages and limitations of solutions.

and then ...

❺ Actively participate in the class discussion. Learning is best when you are an active participant.

❻ Reflect on the case-learning experience. Think about ways you could apply the lessons from the case study to your own life and professional practice.

Become a reflective thinker ...

- View the situation from multiple perspectives. How would each person in the case study view the situation?
- Search for multiple solutions.
- Generate a list of advantages and limitations for each possible solution.
- Take a position and justify it with the evidence in the case.

Characteristics of case studies

- There is no ONE right answer.
- There is more than one way to look at things - there are different points of view.
- Keep an open mind: suspend judgment until all ideas are considered.
- Be leery of assumptions and generalizations: avoid seeing things in the extreme.

Finally

- Expect to get better at analyzing situations over time.
- Focus on your analysis skills.
- Take time to reflect on each case after class.
- Try to apply the lessons from the case study to your personal and professional practice.

Uses of Case Studies

- Primarily for adult learners in training situtations, including recertification.
- Team building activities in organizations.
- Practice client interaction skills.
- Practice use of analytical skills.
- To ask “what if?” questions and review employees basic knowledge.

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Method #3:
Simulations

- Structured situations that imitate real engineering tasks; may or may not use computer software
- Include rules, guiding principles, structured roles and relationships
- Faculty: explain roles, monitor students as they go through the simulation, help students reflect, lead the debriefing
- Debriefing looks for meaning and helps students uncover the intended ideas and principles.

met? Or exceptional customer value? Or personal integrity? And how was that balanced against more traditional goals such as market share and profitability?

Simulation Elements

The most successful educational experiences also are delivered through a combination of the three *delivery elements*, simulation, game, and pedagogical. Getting it wrong with any of the three can cripple an experience.

Simulation elements model reality. Specifically, they can rigorously but selectively represent objects or situations, and can rigorously but selectively represent user interaction. Different simulation elements enable discovery, experimentation, concrete examples, practice, and active construction of systems, cyclical, and linear content. People who learn via simulation elements have a deep and flexible understanding of the material. But too much simulation creates a very dry and often frustrating experience.

Simulation Elements

- *Appropriately used linear, cyclical, and systems content*
- Use of simulation genres, including branching stories, virtual products/ virtual labs, interactive spreadsheets, flight simulator; and 3D maps, as well as *new genres* to be introduced
- *The appropriate use genre elements, including modeling, AI, graphics, and interface*
- *Creating an atmosphere similar to the atmosphere in which the content will be used*
- *Presenting behavior to be modeled or recognized* (Most narratives, instructions, and case studies have a non-interactive simulation aspect, although focusing primarily on linear content)
- *Feedback from a decision (or series of decisions) that shows the natural consequences of the behavior*

Game Elements

Game elements provide familiar and entertaining interactions. Game elements increase the enjoyment derived from an

educational experience. This can drive good will, but more importantly, drive more time spent with the experience, which increases learning. Game elements can surround the other content, and controversially, make it easier or more dramatic. Game elements reduce the need of instructors to "lean" on students, and lower pressure, but too much of it distracts from or waters down the learning.

Game Elements
■ *Simplified or abstract interfaces*
■ Use of established game genres (game shows, athletic competitions, computer games, card games)
■ Clicking as quickly as possible
■ Gambling models
■ *Certain exaggerations of responses to make play more fun*
■ Reliving the roles of heroes or role-models
■ Conflict
■ Shopping
■ *A pause button*
■ A speed-up/slow down switch
■ *A replay option*
■ *Creating order from chaos*
■ Choosing your on-screen character's appearance or *voice*
■ Mastering a simple cyclical skill (throwing a card into a hat, Pacman)
■ *Competition between learners, including facilitated by maintaining lists of high scores*
■ *Accessible communities for competition, and/or sense of belonging*
■ Presenting a mystery or puzzle to solve
■ *Making the player overly powerful or overly relevant in a resolution of a situation*
■ Choosing between multiple skill levels to better align difficulty with capability

Pedagogical Elements

Pedagogical or didactic *elements* surround the game and simulation elements, ensuring that the students' time is spent productively. They better know what is going on and where to

focus their energies. Pedagogical elements in real-life include speedometers, caller ID, and the warning on certain cars that a "Student Driver" is operating them.

In educational experiences, pedagogical elements also help the learners avoid developing superstitious behavior, such as believing they are influencing something by a particular action when they are really not. If there are too many pedagogical elements, however, the learners feel they are engaging a manual, or mindlessly following directions.

Pedagogical Elements

- *Background material (including case studies, visual or text representations of systems models, and descriptions of interfaces to be encountered)*
- *Scaffolding (letting the learner know what is going on and give suggestions, either through voice or graphics)*
- *Diagnostic capabilities (including scoring)*
- *Visualization of relationships*
- Debriefing
- Forced moments of reflection
- Libraries of successful and unsuccessful plays
- *Links to chat rooms where people can brag about how they achieved a high score*
- Tests and *quizzes*
- Acronyms or other pneumonic devices to trigger memory of processes
- Coaching
- Pop-up prompting and help

Virtual Leader **Example**

Redux

I have *italicized* those items in the simulation, game, and pedagogical lists of elements above that we used for the *Virtual Leader* simulation. Here are some specific examples in context:

Simulation elements in *Virtual Leader* include primarily the systems, linear, and cyclical simulation content mentioned before (and visualized all together below), but also the linear

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Method #4:
Muddiest-Part-of-the-Lecture Cards

- Statements by students about the parts of the lecture that are not clear to them

- Procedure:
  - Stop the lecture about 5 minutes before time
  - Distribute 3x5 index cards to students and ask them to write what was the "muddiest" part of the lecture for them, that is, what parts do they still not understand?
  - Collect the cards and group them by similar questions

- Answer the most common questions:
  - At the start of the next class
  - In handouts that you distribute to the class
  - On the class website

- Save the cards to improve your teaching the next time

Muddiest Point in the Lecture (Muddy Cards)

Muddy Cards are One Type of End-of-Class Feedback

End-of-Class Feedback

- Allows student reflection which increases retention
- Assists students in using time to study effectively
- Provides information to instructor in time to correct misconceptions by the next class meeting
- Is more effective than asking for questions
- Assists instructor in planning course for next offering

Muddy Cards – Background

In 1989, Frederick Mosteller's article, "The 'Muddiest Point in the Lecture' as a Feedback Device," appeared in *On Teaching and Learning*: *The Journal of the Harvard-Danforth Center*, Vol. 3, 1989, pp. 10–21.

- Mosteller, a statistics professor at Harvard, advocated using the last three or four minutes of every class to ask students these three questions:
  - What was the most important point in the lecture?
  - What was the muddiest point?
  - What would you like to hear more about?
- Muddy Cards are a variation of the One-Minute Paper technique (Angelo & Cross, 1993, Classroom assessment techniques, 2nd ed., San Francisco, Jossey-Bass) specifically designed to determine gaps in student comprehension

Muddy Cards – General Procedure

- Hand out 3x5 cards near the end of lecture
- Specifically ask for feedback – "In the next 3 minutes, please reflect on the lecture & write down the point you found the muddiest & need clarification about."
- Collect the cards
- Review cards & decide on a format for addressing the muddy points, such as
  - Post questions & answers on course web page
  - Answer questions at start of next class meeting
  - Prepare a handout
  - Include in recitations
  - Send an email to the class

Muddy Cards – Experiences in Aero/Astro courses at MIT

Faculty Experiences

- Usually ask for Muddiest Point only
- Some faculty find their use very informative in planning lectures & future offerings of the course
- Some faculty are disheartened by what they find out from the cards
- It can create a great deal of work for faculty to go through the cards & address the Muddy points if done in a formal way
- A searchable database of common questions/muddy points and their answers is being created & may help with the time factor
- Remind students every 3 weeks about importance of doing muddy cards

Student Experiences

- Many students find them useful
- Students find them most useful when the answers are posted on the web
- Some students feel it helped them focus their study efforts
- Some students found that they became too routine & therefore not useful
- It is unclear whether students are able to judge if/how the use of Muddy Cards affected their retention of the material

Tips for Using Mudddy Cards Effectively

Remind students of the *student* advantages of Mud Cards

- Allows student reflection which increases retention
- Assists students in using time to study effectively by helping them pinpoint what they don't understand - optimizing their study time
- Modern learning theories (e.g. constructivism) suggest that addressing misconceptions and preconceptions is critical for establishing deep conceptual learning (Wandersee, Mintzes and Novak, 1994). Mud Cards provide a data source for determining these misconceptions.
- Some educational researchers believe that students pay greater attention to the lecture if they are expected to identify a muddiest point (Angelo & Cross, 1993)

Advantages to Faculty

- Provides information to instructor in time to correct misconceptions by the next class meeting
- Assists instructor in planning the course for the next offering

To Obtain Student Participation

Faculty need to:

- End the lecture 3 minutes early and specifically ask for feedback - "In the next 3 minutes, please reflect on the lecture & write down the point you found the muddiest & need clarification about."
- Encourage participation and avoid disruption by requiring all to remain seated until the 3 minutes have passed
- Respond in some way to the cards; if there is no response students get the message that their feedback is not valued. Here are some ways to respond:
  - Post questions & answers on course web page
  - Answer questions at start of next class meeting
  - Prepare a handout
  - Include in (or ask TAs to include in) recitation
  - Send an email to the class

Some Alternatives to "Muddiest Point of the Lecture"

- In addition to or instead of "What was the muddiest point?" ask
  - "What was the most important point in the lecture? (also called One Minute Paper)" or
  - "What would you like to hear more about?" or
  - "I was surprised to learn . . " and ask students to complete the sentence
- In large classes, break students into small groups and ask each group to create a card
- If the technique is getting stale, use it every two or three lectures instead of every lecture