Self-directed Learning: From look-ahead homework to a flexible engineering degree

David L. Darmofal
Aeronautics & Astronautics
Massachusetts Institute of Technology
A Continuum of Self-directed Learning Strategies

- Independent study
- Assignment(s) in a course
- Project(s) in a course
- Flexible degrees
Course Overview (MIT 16.100)

• Disciplinary subject in aerodynamics

• Enrollment typically around 40 students (juniors and seniors)

• Students will have previous fluid dynamics in sophomore year

• Not quite a required course but 2/3’s of students take it

• Course topics include:
  - Incompressible, subsonic, transonic, and supersonic flows
  - Viscous flows with an emphasis on boundary layers
  - Wind tunnel testing and computational methods
16.100 Pedagogy: Then and Now

Then (pre-1999):

- Traditional lectures
- Weekly homework assignments after lectures on material
- Written exams
- Short (two week) team-based design project

Now:

- Concept questions & mini-lectures in most class periods
- Look-ahead (graded) homework assignments
- Written take-home exams followed up with oral exams
- Semester-long, team-based design project
Using Concept Questions

• Pose concept question
• Ask students to indicate their answers: we currently use handheld electronic response system (iClicker)
• If most students have the correct answer, give a brief explanation, then move on
• Else, clarify concept:
  ▪ have students discuss with neighbors,
  ▪ give mini-lecture on concept and answers
• Take another poll of students’ answers
• A typical class period will include about 2 concept questions
Irrotational Flow Concept Question

Given the following streamlines for a steady, 2-D flow:

Which of these flows is irrotational:

(1) Only (a)
(2) Only (b)
(3) Both (a) & (b)
(4) Neither
(5) Not enough information
Look-ahead Assignments

• **Problem**: to address conceptual understanding in-class, students must begin learning beforehand

• **Solution**: Reading and homework assignments due prior to in-class discussion of material

• Homeworks are at same level as in past years when given after class
Advantages of Look-ahead Assignments

- Leverage existing resources for basics & derivations while permitting faculty to be value-added in classroom
- Classroom interactions can focus on concepts
- Encourage self-directed learning
- Improve feedback time
- Homeworks can be designed to demonstrate typical misconceptions
Importance of Student Preparation for Lectures

• Effective implementation of concept questions is not trivial and impacts entire pedagogy

• In Fall 2000, we implemented concept questions in-class but look-ahead assignments were too simplistic

• The Fall 2000 experience led directly to the current implementation in which look-ahead assignments were at the same level as previous years post-lecture assignments
Student Evaluations of Pedagogy: Reading & Homework

Reading & hw more effective with increased hw difficulty
Student Evaluations of Pedagogy: Lecture

Lecture more effective with increased hw difficulty
“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], hw 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.”

“I really like the format of the class, I think it’s actually a very good way to format a course. At first I didn’t like how the homework was really tricky and it always came before we went over the material in lecture, but after a little bit I didn’t mind it.”

“Doing homework before the lectures is good… makes actual learning in lectures possible.”
A Continuum of Self-directed Learning Strategies

- **Student**: Independent study
- **Course**: Assignment(s) in a course, Project(s) in a course
- **Program**: Flexible degrees
Learning objective:
Allow students to gain greater depth of understanding and skill in addressing multidisciplinary and interdisciplinary aerospace engineering problems.
Degree comparison

16-1
SB in Aerospace Engineering

Aerospace Experimental Projects Lab/Hands-on, Aerospace Capstone Design Subjects

Choose 4 out of 9 aerospace disciplinary subjects

3 second-level core subjects

Unified Engineering

16-ENG
SB in Engineering

Aerospace Experimental Projects Lab/Hands-on, Aerospace Capstone Design Subjects

Choose 6 coherent subjects (3.5 in engineering and 1 in math or science)

1 second-level core subject

Unified Engineering

General Institute Requirements
Course 2-A (i.e. flexible degree) in existence since 1934
Course 2-A became ABET accredited in 2002
Work of Peko Hosoi, Professor in Mechanical Engineering, MIT

Confidence Levels of 2 versus 2-A (current students)

- Apply Technical Knowledge
- Evaluate Technical Concepts
- Team Work
- Communication
- Other

- Set a precise project plan that maps out task order for a major project
- Apply economic concepts in market analysis

Course 2-A vs. Course 2
Conclusions

• Look-ahead assignments requiring significant self-directed learning improve effectiveness of concept-based lecturing

• Though initially hesitant, students recognize the benefits of these ‘non-traditional’ pedagogies

• Flexible degrees may provide a method to improve training of engineers to solve complex societal problems

• Flexible degrees offer a programmatic avenue for self-directed learning