Mapping Topics & Learning Outcomes across the curriculum

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Outline

Mapping  What and why?

Topics mapping  http://crosslinks.mit.edu/

Outcomes Mapping  http://Xoces.mit.edu/

Fly-by-Wire  http://fbw.mit.edu
What do we mean by mapping?

A visual depiction of the landscape
How to get from place A to place B
Why map?

To understand and document what we are teaching

1. Catalog learning outcomes and prerequisite relationships

2. Maintain unified repository for outcomes across the Institute ("sequencing the DNA of the MIT undergraduate curriculum")

3. Communicate clear expectations to students
Why map?

To connect the pieces

4. Contextualize learning for students by providing roadmap

5. Connect faculty across subjects, departments, schools

6. Catalyze discussion about different types of outcomes and what it means to be a graduate of the mapped program (cf. CDIO, ABET)
Why map?

To enrich our ability to revisit, refresh, re-use learning resources

7. Make modular learning and assessment resources readily available with context

8. Navigate easily through related learning resources

9. Connect resources to specific outcomes
Why map?

To inform our future educational innovations

10. Identify opportunities for modularity in the curriculum
11. Identify opportunities for flexibility in the curriculum
12. Create opportunity for competency-based assessment
13. Enable differentiated/personalized education and automatic recommendations
Accessing targeted, modular resources for granular topics

Mapping how topics connect across the curriculum

Gathering insight into student learning and behavioral patterns
**FIVE FACETS OF COMPREHENSION**

1. **Prepare** shows the prerequisites for a certain topic. The prerequisite chain enables the student to identify "gaps" and critical points in her abilities.

2. **Relate** shows closely-related topics for a certain topic. Through seeing related topics across MIT, the student gains a big picture understanding.

3. **Learn** is a collection of links to course notes, modular videos and mathlets that teach the topic. This aggregated collection of modular material enables the student to easily refresh specific topics.

4. **Advance** shows topics that follow after the current one. By seeing which topics lie ahead, the student grasps the motivation and context for the current topic.

5. **Apply** is a collection of links to interesting applications of the topic in later courses or in industry usage. This section answers the question, "How is this useful in the real world?"

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**Crosslinks.mit.edu**
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This section answers the question, “How is this useful in the real world?”
How are resources accessed?

- MIT OCW
- L’hôpital’s rule
  - All Topics
  - Linear approximation
  - Quadratic approximation
  - ~3m.
  - ~30s.
  - Indeterminate forms
  - Limit
- ~4m.
- ~3m.
- ~6m.
- ~8m.
- L’hôpital’s rule

*Truncated for illustration purposes*
Which resources are accessed?

Khan Academy Videos and Exercises: L'Hopital's rule introduction, examples, and ~20 views

*Truncated for illustration purposes
What do students like?

• Students like modularity
  – “I like it that things are organized by topic. It’s more concise.”

• Students like aggregation
  – “It’s so useful to have everything in one place.”

• Students like the specific MIT angle
  – “It’s good to know that all this has been edited and vetted by MIT people, so I know it’s going to be useful for my MIT work.”

• Students do care about the big picture, even if it’s not materially impactful
  – “It’s interesting, and I think it must be subconsciously helpful when I’m learning it, but I don’t think it’ll actively lift up my grade. But I do think about how things connect together.”
Xoces
outcome exploration system

Prerequisite outcome
An outcome that a student is required to have achieved before s/he can achieve another related outcome

Module
A learning unit comprising a set of outcomes (generally relatively self-contained)
MIToces outcomes mapping at MIT

More than 1400 outcomes collected across 29 subjects

All AeroAstro subjects in UG curriculum that contribute towards degree requirements

Freshman physics, math, chemistry
SUTDoces
outcomes mapping at SUTD

1 common core + 4 pillars

50 subjects

295 outcomes
Using the map at MIT and SUTD

- Are there better ways to organize and sequence content?
- What opportunities exist for modularity in the curriculum?
- How do the Freshmore year classes connect to the Sustainable Design pillar?
- How do integrated Freshmore classes (e.g., ChemBio, MathPhysics) change the overall curriculum map?
- What role do design activities play in synthesizing outcomes across the curriculum?
- ...
FLY-BY-WIRE

Towards Scalable Differentiated Instruction
Inspired by ideas from aerospace engineering, Fly-by-Wire (FbW) is a blended learning technology for instructors to provide scalable, differentiated instruction.

FbW is a U.S. Department of Education FIPSE First in the World Development Project

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FbW Project
Motivation

Pain points in the classroom today & how technology can help.

• Instructors teach multiple sections; heavy workloads
• Students have different backgrounds & levels of ability
• Difficult to track an individual student and give targeted feedback
• Students have work / life commitments outside of school
• Streamline lower-level tasks that take up instructor time
• Assess an entire class’ ability and fill in inadequate backgrounds
• Record performance and rapidly deliver targeted feedback
• Can be used outside of the classroom, providing flexibility
FbW Project Objectives

• Develop FbW intervention to enable instructors to provide scalable, differentiated instruction
• Develop instruments to measure impact of intervention
• Conduct quasi-experimental study at Arapahoe and Quinsigamond Community Colleges
• Measure quantitative improvement in student outcomes (learning outcomes, time to completion, persistence, retention, etc.)
• Collect qualitative feedback from instructors using the intervention (perceived impact on faculty workload, student interaction, ability to adjust to classroom demands, use of in-class time)
What is a “fly-by-wire” system?

Since the flight-control computers continuously "fly" the aircraft, pilot's workloads can be reduced.

source: wikipedia

“Fly-by-wire technology has allowed Airbus to develop a true family of aircraft through the highest degree of operational commonality.”

source: www.airbus.com
The Aero Analogy in the Classroom
An “open-loop” system

desired roll angle → pilot → control action → aircraft actuators → rolling moment → airplane → achieved roll angle

*actuators are the things that move, e.g. moving surfaces on the wing*
An “open-loop” system

The open-loop system is **vulnerable**
- to disturbances
- to variations in air conditions from day to day
- to variations from aircraft to aircraft
An “open-loop” system

Pilot

Desired roll angle -> Control action -> Actuators

Rolling moment -> Roll angle

Disturbance (wind)

Instructor

Desired outcome -> Learning resources -> Student

Disturbance

Achieved outcome
Closing the loop with sensing & feedback

- desired roll angle → pilot
- control action → actuators
- rolling moment → airplane
- disturbance (wind) → airplane
- achieved roll angle → pilot

Visual observation senses the actual aircraft roll angle...

...and feeds it back to the pilot, who then adjusts the control action accordingly.
Closing the loop with sensing & feedback

- Pilot
  - Desired roll angle
  - Control action
  - Actuators
    - Rolling moment
    - Achieved roll angle
  - Visual observation

- Airplane
  - Disturbance (wind)

- Instructor
  - Desired outcome
  - Learning resources
    - Visual observation & assessment-driven feedback (but with delay)
  - Student
    - Achieved outcome
A digital feedback control system

- Desired roll angle
- Control logic determines corrective action as a function of the error
- Actuators
- Airplane
- Disturbance (wind gust)
- Achieved roll angle
- Sensors
- Comparator compares the desired and the achieved roll angle
- Sensor system senses the actual aircraft roll angle
A digital feedback control system

- Desired roll angle
- Control logic
- Actuators
- Airplane
- Sensors
- Disturbance (wind gust)
- Achieved roll angle

- Desired outcome
- Control logic
- Online learning resources
- Student
- Automated assessments
- Disturbance
- Achieved outcome
Pilot + computer $\rightarrow$ Fly-by-Wire system

- **pilot**
- **control logic**
- **actuators**
- **airplane**
- **sensors**
- **sensors + visual observation**

**desired roll angle**

**disturbance** (wind gust)

**achieved roll angle**
Pilot + computer → Fly-by-Wire system

- Pilot
- Control logic
- Actuators
- Airplane
- Desired roll angle
- Disturbance (wind gust)
- Achieved roll angle
- Sensors
- Sensors + visual observation

- Instructor
- FbW logic
- FbW actions
- Student
- Desired outcome
- Disturbance
- Achieved outcome
- FbW assessment
- FbW & other assessment + visual observation
Pilot + computer → Fly-by-Wire system

- **desired outcome**: instructor
- **disturbance**: FbW logic → FbW actions → student
- **achieved outcome**: FbW & other assessment + visual observation

FbW logic and FbW actions are assessed by the instructor, and the feedback loop is completed with visual observation.
Proposed FbW system for education

FbW is more than just an analogy— it is a structured framework for designing the components of our system.

FbW logic
- mapping the relationships among outcomes, and the linkages between assessments and outcomes
- designing and developing the FbW assessments (sensor system)
- designing the FbW logic and FbW action reacting to student response (controller logic, actuators)

FbW technology
- designing and creating the student-facing and instructor facing apps
- designing and developing the technology to be flexible, modular and open-source
Summary

**Mapping**  What and why?

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