TOWARDS A NEW UNDERGRADUATE CURRICULUM IN MATERIALS SCIENCE & ENGINEERING

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Massachusetts Institute of Technology
Cambridge, Massachusetts
Motivation: pushes

1. disturbing trend in enrollment

2. dissatisfaction among students:
   * feel ill prepared (weak in math, quantum mechanics, probability & statistics, k-space, numerical methods, data analysis, design, leadership/management)
   * find program boring (too easy, lacks rigor & context)
   * no clear theme (no obvious sequence, much repetition, no evident coordination)
   * feel that faculty place lowest priority on u.g. program, c.f. research, consulting, committee assignments

3. drop in ratings in *US News & World Report*
Motivation: pulls

4. advances in information systems: implications for engineering education?

5. renovation of Building 8: unique opportunity linking space changes to curricular changes
The Process

1. department head (Subra Suresh) names a leader (Donald Sadoway) who chooses his committee “UCC”
2. brainstorming among committee members
3. data gathering among different stakeholders
4. committee develops draft program at the level of storyboards and presents this to the entire faculty for discussion
5. faculty teams tasked to develop syllabuses for suites of subjects within the same time blocks (by semester)
The Process

6 adoption of syllabuses by entire faculty
   green light to develop subject contents at the level of lecture topics

7 development of subject content with close interaction with coordinators, e.g., math, lab, professional development
   continuity, completeness, objectivity

8 communication with various Institute committees to prepare for necessary approvals
The Goal of a MSE Education

to educate specialists
in the development and use
of materials in technology
The Course of Study

- core technical knowledge
- professional development
- capstone activity
Pedagogical Considerations

• integration of subject matter (crosstalk)
• reinforcement via application
• need-to-know delivery of content

high sticking coefficient
Core Technical Knowledge

subject matter falls into 3 blocks

- synthesis & processing
- composition & structure
- properties & performance
Storyboard Fall Year 2

- Orientation
  - Energetics
  - Structure
  - Math

- Laboratory
  - Energetics
  - Structure
  - Math
# Schedule - Fall Year 2

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- **Laboratories**
- **Orientation**
- **Vacation days**
## Schedule - Fall Year 2

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- **Lecture (Blue)**
- **Recitation (Red)**
## Schedule - Fall Year 2

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- **M**: Lecture
- **T**: Recitation
- **W**: Laboratory
Sample Storyboard - Fall Year 2

Orientation: What is MSE?
Materials & History
Current Trends in the field of MSE
Career Opportunities & Pathways
Unifying Theme of Course 3

- view of the “big picture”
- motivated to study fundamentals
- esprit de corps

first week
<table>
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<tr>
<th>09/18</th>
<th>Building descriptions of solids from the ground up</th>
<th>QUANTIZATION OF ENERGIES, AND THE BIRTH OF INTERACTIONS</th>
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<tr>
<td></td>
<td>- boundary conditions → quantization of energies: the infinite well</td>
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<td>- well becomes finite – electrons spread out</td>
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<td>- two wells getting closer…</td>
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<td><strong>Application Example:</strong> stationary waves in organ pipes and drums. Tunneling behavior of electrons (STM).</td>
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<td>HOW DO WE CONNECT THE ATOMS AND MOLECULES OF A MATERIAL TO THERMODYNAMIC FUNCTIONS?</td>
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<td>- the use of simple models to consider many atoms in a material</td>
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<td>- introduction to microstates</td>
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<td>- microstates and energy: role of heat: energy levels are fixed; occupation changes!</td>
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<td>- averaging, ensembles, and the premise of statistical mechanics (two postulates of stat mech)</td>
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<td>- our first prediction, using the microcanonical ensemble: behavior of an ideal gas</td>
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<td><strong>Application Example:</strong> How does our calculation compare with the behavior of real gases?</td>
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- Multivariate calculus partial derivatives extrema of multivariate functions integrating multivariate functions Need series approximations here? ODE Boundary conditions separation of variables

- thermo

- math

- structure
Laboratories

- new equipment
- ~2000 sq. ft. additional space
- new content:
  - biomaterials
  - chemical synthesis
  - elec. mat. characterization
New Undergraduate Laboratory
Compare to this typical scene
Compare to this typical scene
Much better!
Communication skills developed

lab reports in various formats:
  - memo
  - journal article
  - technical report
  - oral presentation

lab books graded!
Storyboard Spring Year 2

- kinetics of time
- μstructure
- evolution
- electronics
- photonics
- magnetics
- elective

Time
Storyboard Fall Year 3

- Materials
- Response
- To stress
- Chemistry
- Organic
- Elective

Time

Units

Laboratory
Restricted Electives: “Frontiers of the Field”

- subjects running 4 - 7 weeks (also Parts 1, 2, etc.)
- content builds on core and moves to the frontiers of the field
- shorter period has many advantages:
  1. lowers barrier to innovation
  2. avoids repetition and stretching
  3. more likely to sustain student interest
  4. much greater exposure to topics and faculty
Storyboard - Fall Year 4

14 weeks

time →

units

RE1  RE2

RE3  RE4
Storyboard - **Spring** Year 4

**Choice of Capstone Activity:**
- Senior thesis
- Industrial internship
- Interdisciplinary design studio
- Educ. design project: new lab module

Units:
- RE7
- RE8
- RE9

Time: 14 weeks
High Resource Intensity

- lab is very costly!
- hire full-time lab manager
- double-teaming of faculty
- share workload
- student exposure
- enable synergy
- TAs for media development
Timeline to Fall 2003 Launch

Spring 2003
- lecture plans of Y2
- laboratory content of Y2

Summer 2003
- finalize content of Y2
- curriculum development of Y3

Fall 2003
- launch Y2 and open new teaching lab
Timeline to Fall 2004 Launch

Spring 2004
- lecture plans of Y3
- laboratory content of Y3

Summer 2004
- finalize content of Y3
- curriculum development of Y4

Fall 2004
- launch Y3
Initial Reactions to Fall 2003

- labs integrated knowledge well from thermo & structure
- much more lab experience:
  old -- 16 h/mo for 2 semesters
  new -- 12 h/mo for 4 semesters
- scheduling labs difficult
  each student does a subset of labs
  non-uniformity of experience
“We are surrounded by insurmountable opportunities.”

- Pogo