New Engineering Education Transformation (NEET)

Babi Mitra
Executive Director, NEET
MIT

Technische Universiteit Eindhoven
May 17th, 2018
The NEET Charter
from the Dean of Engineering

The program will...
• be built on the established principles of MIT
• focus on new machines and systems

via...
• a balanced approach to analysis and synthesis
• a foundation in modern engineering pedagogical approaches

BOLD change on potentially large scale at MIT
“... that will best serve the nation and the world in the 21st century.” (from MIT Mission)
The Culture and Values of MIT

- **Useful knowledge (1861)** “… in industrial society, science and technology were legitimate foundations for higher knowledge…”

- **Societal responsibility (1861)** “… to apply the fruits of scientific discovery to the satisfaction of human wants”

- **Learning by doing (1861)** “… converting personal experience into knowledge.”

- **Education as preparation for life (1949)** “… provide students with an education that better prepares engineers to function as professionals…”

- **The value of fundamentals (1949)** “… education should be based on the fundamental principles…”

Summarized in the Task force on Student Life and Learning 1998
What are the grand challenges our students will need to address in their professional career?

Our Engineering students will address these grand challenges by building the NEW MACHINES and SYSTEMS.
Old Machines → New Machines

Flying Machines

1950’s “Old Machines”  Today’s “New Machines”

New Machines and Systems include constructs that engineers build: mechanical, informational, biological, energetic, molecular, infrastructural
Attributes of New Machines & Systems

- Integrate: mechanical, informational, molecular, biological, and energetic components
- Complex
- Highly networked and part of larger systems of systems
- Higher levels of autonomy and independence of action
- Support a sustainable environment
Four NEET Student Focused Principles

• Prepare you to develop the new machines and systems
• Prepare you to be makers, discoverers or on the spectrum
• Shape your education around the way you best learn
• Teach you the NEET Ways of Thinking --- how to think and learn more effectively by yourself
The NEET Team

- **Core NEET Committee**
  - **Ed Crawley**, Aeronautics and Astronautics, co-lead NEET
  - **Anette ‘Peko’ Hosoi**, Mechanical Engineering and Associate Dean, School of Engineering, co-lead NEET
  - **Markus Buehler**, Head, Department of Civil and Environmental Engineering
  - **Kris Prather**, Chemical Engineering
  - **Geoff Beach**, Materials Science and Engineering
  - **Jeffrey Lang**, Electrical Engineering and Computer Science
  - **Mark Bathe**, Biological Engineering
  - **Michael Short**, Nuclear Science and Engineering
  - **Bruce Tidor**, Electrical Engineering and Computer Science
  - **Gerry Sussman**, Electrical Engineering and Computer Science

- Executive Director, Babi Mitra
- Students@NEET
- Task Groups: Projects; Curriculum; Governance; Program Assessment
- Thread faculty teams --- four teams
The Strategy for implementing NEET at MIT --- it’s a culture change, go slow to go fast

• We spent the first couple of months meeting and discussing how we wanted to go about it, rather than jumping into action

• Our goal was to examine different options and find an initial approach that would cause the least perturbation in the system

• The first step was to gather evidence from stakeholders --- thought leaders, global benchmarking, industry, faculty, alums, students, DHs, dean and president and do our homework on what was available
  – Use existing flex degrees during pilots
  – Do not need to ask for any changes in the faculty rules

• Aim for 7-8 cross-disciplinary threads with about 50 students in each, ~40-50% of the engineers

• Decide on final form of program by about Spring 2020
Survey of MIT freshmen, “Engaging GIRs” by MIT students Emma Bingham, Mike Winer, Mo Eltahir, Becca McCabe, Design your First Year experience (DFY)
Proficiencies expected from MIT engineers
Feedback from industry
**Current Leaders: Olin, MIT, Stanford, Aalborg, TU Delft**

<table>
<thead>
<tr>
<th>Key attributes of the ‘current leaders’</th>
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</thead>
<tbody>
<tr>
<td>Established international profile</td>
</tr>
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<td>Educational excellence confined to ‘pockets’</td>
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<td>Emphasis on external engagement and educational collaborations</td>
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**Pedagogical features include:**

- Pathways and linkages for students to engage with the university’s research
- A wide range of technology-based extra-curricular activities and experiences
- Multiple opportunities for hands-on, experiential learning
- The application of user-centered design throughout the curriculum
- Emerging capabilities in online learning and blended learning
- Longstanding partnerships with industry that inform the engineering curriculum

*From “The Global State of the Art in Engineering Education”, Ruth Graham, commissioned by MIT-NEET, 2017-18*
Emerging Leaders: Olin, SUTD, UCL, Pontifical Catholic, Charles Sturt

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<th>Key attributes of the ‘emerging leaders’</th>
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<td>Systemic and unified educational approach (either as a ‘new start’ university or as the product of systemic reform)</td>
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<td>The development of the program is likely to have been shaped by regional needs and constraints</td>
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<td>The educational approach includes at least three of the following:</td>
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<td>• non-conventional student entry requirements or selection processes</td>
</tr>
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<td>• the increasing integration of work-based learning</td>
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<tr>
<td>• the blending of off-campus online learning with on-campus intensive experiential learning</td>
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<tr>
<td>• the establishment of student-led, extra-curricular activities in contexts and cultures that are not typically associated with non-curricular experiences</td>
</tr>
<tr>
<td>• a dual emphasis on engineering design and student self-reflection</td>
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*from “The Global State of the Art in Engineering Education”, Ruth Graham, commissioned by MIT-NEET, 2017-18*
Evolution of Ideas

**Evidence**
- Thought leaders
- Benchmarking
- Industry
- Alumni
- Students
- Faculty

**Principles**
- New Machines
- Makers and discoverers
- Pedagogy to support how students learn
- Ways of thinking
- Bold

NEET Project-Centric Model & NEET Threads

neet.mit.edu
The Timeline for Implementing NEET at MIT --- Aug 2016-Sep 2017 launch

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<td>Launched two Pilot Threads</td>
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</table>
The Current Subject Centric Major Scheme

Subjects 1 → Subject 2

Subject 3

Project

All modules also yield learning retained for life
NEET Project Centric Curricular Construct

Subject 1

Self Study

Subject 2

Self Study

First year

Project A (sophomore)

Digital Learning

Personal and interpersonal coaching

Project B (junior)

Digital Learning

Personal and interpersonal coaching

4th year

All modules also yield learning retained for life
NEET Projects: progression of learning outcomes --- an example

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpersonal</td>
<td>Interpersonal</td>
<td>Small group</td>
<td>Larger group</td>
</tr>
<tr>
<td>Context</td>
<td>Building on fundamentals</td>
<td>Implementation, operations, QC</td>
<td>Market and finance issues</td>
</tr>
<tr>
<td>Computation</td>
<td>Simple tools</td>
<td>Computational tools</td>
<td>Advanced tools</td>
</tr>
<tr>
<td>Personal</td>
<td>Decisions, ethics integrity</td>
<td>Initiative, judgment</td>
<td>Responsibility, flexibility</td>
</tr>
<tr>
<td>Self learning</td>
<td>Builds on subjects</td>
<td>Self study of common topics</td>
<td>Professional self study</td>
</tr>
</tbody>
</table>
NEET Threads

Student gets a Degree in a Major

Students gets a Degree in a Major + a Certificate in a NEET Thread (Diagonal)

- Faculty
- Disciplines
- Quality

NEET Thread
- New Machines +
- Project-centric (application oriented)
- Cross-departmental

neet.mit.edu
What will an MIT student get in NEET?

an undergraduate degree in their major from the School of Engineering

+ a Certificate in the Thread from the School of Engineering

In order to gain a NEET Certificate, they must complete the following:

• An undergraduate degree in the School of Engineering
• The core of subjects for the thread
• The three or more NEET projects in the thread, including at least one each in the sophomore, junior and senior year
• A set of advanced elective courses in the context of the thread
• The NEET Intellectual Diversity Requirement.
• The NEET Seminar
Principle #4 – we should teach students how to think and learn by themselves

NEET Ways of Thinking
• These are our high level learning outcomes

[Diagram showing various categories such as Making, Discovering, Personal, Interpersonal, Creative, Critical and Metacognitive, Analytic, Computational, Experimental, Humanistic]
### Integration of NEET Ways of Thinking into Threads --- An example

<table>
<thead>
<tr>
<th>NEET Ways of Thinking</th>
<th>Thread Subjects</th>
<th>Thread Projects</th>
<th>Science GIRs</th>
<th>HASS GIRs</th>
<th>Other*</th>
<th>Co-Curricular</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Making</strong> - Innovating, by inventing and bringing about artifacts that have never before been in existence: Conceiving (understanding needs and technology, and creating concept), designing, implementing and operating products and systems that deliver value</td>
<td>✓</td>
<td></td>
<td></td>
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<tr>
<td><strong>Discovering</strong> - Advancing the knowledge of our society and world by exploring, identifying, and generating new learning, often by conducting research that employs scientific methods and leads to new fundamental discoveries and technologies</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>Thesis UROP</td>
</tr>
<tr>
<td><strong>Interpersonal Skills</strong> - Engaging with and understanding others: communicating, listening, dialog and emotional intelligence, working in and leading teams, collaboration and networking, advocacy and leading change</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>Comm Req ✓</td>
<td>GEL Ath Lib</td>
</tr>
<tr>
<td><strong>Personal Skills and Attitudes</strong> - Initiative, judgment and decision making; responsibility and urgency; flexibility and self-confidence; acting ethically and with integrity; social responsibility; dedication to lifelong learning</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
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<tr>
<td><strong>Creative Thinking</strong> - Forming something new and somehow valuable, for example by focusing thought, incubating new ideas, illuminating them in conscious awareness, and verifying</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td><strong>Systems Thinking</strong> - Predicting emergence of the whole by examining of inter-related entities in context, in the face of complexity and ambiguity, for homogeneous systems and systems that integrate multiple technologies</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
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<tr>
<td><strong>Critical and Metacognitive Thinking</strong> - Assessing the worth or validity of something that exists, by analyzing and evaluating information gathered from observation, experience or communication</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>Lib</td>
</tr>
<tr>
<td><strong>Analytical Thinking</strong> - Working systematically and logically to break down facts and resolve problems, identify causation and anticipate results, often by applying theory, modeling and mathematical analysis</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
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</tr>
<tr>
<td><strong>Computational Thinking</strong> - Using computation to understand physical, biological and social systems by applying the fundamental constructs of computer programming (abstractions, modularity, recursion), data structures, and algorithms</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Experimental Thinking</strong> - Conducting experiments to obtain data: selecting measurements, determining procedures to validate data, formulating and testing hypotheses</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lab Req ✓</td>
</tr>
<tr>
<td><strong>Humanistic Thinking</strong> - Developing and and exploiting a broad understanding of human society, its traditions and institutions: knowledge of human cultures, human systems of thought, the social, political and economic frameworks of society; and modes of expression in the arts</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
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* Communication Requirement and Laboratory Requirement

Chatbot: neet.mit.edu
Implementation of NEET --- Fall 2017

• Programs launched as pilots in September 2017
  – Autonomous Machines
    • 31 students in autonomy and robotics: aero & astro, EECS, mech eng
  – Living Machines
    • 12 students in biomedical diagnostics and therapeutics: biological eng, mech eng, chem eng, EECS

• 43 engineering sophomores joined (~ 5% of engineers)
Autonomous Machines (John How – 16)

- 3 students from aeronautics and astronautics (16)
- 17 students from mechanical engineering (2)
- 11 students from electrical engineering and computer science (6)
Autonomous Machines

- Fall 2017 – 3 unit Seminar on AM that introduced technology, research opportunities and ways of thinking
- Spring 2018 – 2.S007, a 12 unit special section of 2.007 Design and Manufacturing I
  - Plus 16.201, a 3 unit *supervised* bridge module on statics and mechanics using MITx
  - Plus 16.S886, a 3 unit module on sensors and robotics
  - Space provided by Course 2 and 16
Autonomous Machines Thread

• Upper-class subjects and projects

• Major Choices

• Sophomore subjects
NEET Autonomous Machines
Core subjects, projects and recommended electives

• **Core subjects:**
  – Mechanics (16.001 or 2.001)
  – Introduction to Programming (6.01+6.S080 preferred = 2.086, 6.0001+6.0002 accepted)
  – Signals and Systems (6.003 or 16.002)
  – Controls (2.004 [which has 2.003 as a prereq] or 16.06)
  – Math (12 units from 2.087, 6.041a, 6.041b, 6.042, 18.03)

• **Projects:**
  – Design and Manufacturing (of Robotic Systems) (2.S007, a section in 2.007)
  – Advanced Autonomous Robotic Systems (16.AARS)

• **Recommended electives:**
  – A second math subject from the list above
  – Fundamentals of Programming (6.009)
  – Feedback Control (2.14 or 16.30)
  – Introduction to Robotics (2.12)
  – Autonomy/AI (6.034 or 16.410)
  – Human Factors (16.400)
  – Real-time Systems (16.35)
  – Machine Learning (6.036)
  – Measurement/Machine Vision (2.671 or 6.801)
  – Electronics/Microprocessors (2.678 or 6.115)
NEET Autonomous Machines --- sophomore year
Sophomore Spring’18/19 – 2.S007: content is a work in progress

Junior Spring’19 – 6.141: course exists (1 NEET student taking it) and running smoothly

Senior Fall’19 – 16.XX: course and project still under design

Soph Fall’18 – convert the 3-unit seminar class into pre-2.007 course on autonomy
Living Machines (Linda Griffith and Eric Alm, 20 + 2, 10)

- 4 students from biological engineering (20)
- 3 students from mechanical engineering (2)
- 3 students from chemical engineering (10)
- 2 students from electrical engineering and computer science (6)
Living Machines

- Fall 2017 – 3 unit Seminar on LM that introduced technology, research opportunities, early professional skills
- Spring 2018 – 20.S900, a 6 unit project class in cells, hardware and modeling
  - Plus related UROPs with Griffith, Alm and others covering synthetic biology to microfluidic design
  - Plus BE students taking 20.309[J] project class
  - Space provided by Course 20
Lessons Learned from Students

• What do sophomores in the first NEET cohort like about NEET?
  – Cross-departmental academic community
  – Greater exposure to project classes
  – Access to highly sought-after classes
  – Mentoring by NEET faculty who can help shape my path
  – In areas that are likely to be in demand when I graduate
  – The duration of my degree will remain the same

• What sophomores want to be improved:
  – Project experience start in the sophomore fall
  – Could work in small groups and vertical teams
  – More optional lectures and workshops
  – Need better clarity on roadmaps
  – More flexibility
  – Sort out schedule conflicts

• Deferring choice of major is a valuable option (TBC)
  – Deferring choice of major is possible for two majors, hard for three, was not operative this year
Deferred Major Option

Major 1

Deferred Major Core

Major 2

First Year
Other Lessons Learned

• **Modules of knowledge for projects**, an important role of digital learning

• **Other schools (and various initiatives)** very interested in participating

• **Two types of students ---**
  – Those who know what they want to do, but it’s at a boundary or involves projects – no special sophomore year considerations
  – Those who don’t know what major they want, but know a general area or topic – for them a common sophomore year is desirable

• **Seminars are important for:** cohesion, student - faculty community, small projects, some “ways of thinking”, research overviews and career advice

• **Advising students ---** need to have cadre of NEET mentors coordinated with departments’ to support and guide students

• **Clearer role of host departments**

• **Need to develop faculty community**

• **Rebalancing the school ---** need to be more explicit about how we will make a diode or check valve to migrate students to smaller departments

• **NEET ‘appeals well’ ---** to academic thought leaders, industry and donors
### The Timeline for Implementing NEET at MIT --- till now

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<td>Sep 2017</td>
<td>Launched the first 2 Pilot Threads</td>
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<tr>
<td>Oct 2017</td>
<td>RFP for next round of New Threads</td>
</tr>
<tr>
<td>Nov 2017</td>
<td>Preliminary Plans for NEET Pilot Threads that could possibly be launched in Fall 2018</td>
</tr>
<tr>
<td>Jan 2018</td>
<td>Received detailed Thread Proposals</td>
</tr>
<tr>
<td>Mar 2018</td>
<td>Announced Threads for Fall 2018</td>
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Highlights of NEET Operations for 2016-19

Figure 3: Highlights of NEET Operations for 2016-19

Threads:
- Advanced Materials Machines (AMM)
- Autonomous Machines (AM)
- Living Machines (LM)
- Low Carbon Energy Systems (LCES)

Ongoing activities: NEET Seminars, recruitment of staff, program assessment, resource development, cross-school initiatives, NEET Academy, advising, building community, space, communication, presentations

2016-17

2017-18

2018-19
NEET Implementation --- Fall 2018
91 freshmen have signed up
~ 11% of engineers

• **Advanced Materials Machines** (Elsa Olivetti 3, John Hart 2)
  • *If you are interested in Courses 3-A or 2-A*

• **Autonomous Machines** (Jon How 16, Sangbae Kim 2, Tomas Lozano-Perez 6. NEET Instructor Greg Long)
  • *If you are interested in Courses 16-ENG, 2-A or 6-2*

• **Living Machines** (Linda Griffith/Eric Alm 20, Xuanhe Zhao 2, Chris Love 10. NEET Instructor Timothy Kassis)
  • *open to all MIT undergrads in technical degree programs. The majors of current LM students include 20, 2/2-A, 10/10B, 6-2/6-3 and 4-B*

• **Low Carbon Energy Systems** (Mike Short 22/Oral Buyukozturk 1)
  • *If you are interested in Courses 22, 1 or 2-A*
NEET Process of Renewal

MIT Research $\rightarrow$ Influence $\rightarrow$ Projects $\rightarrow$ Graduates

Subjects $\rightarrow$ drive $\rightarrow$ Subjects

Projects $\rightarrow$ support $\rightarrow$ Projects

Influence

Evolving Industrial Practice

young researchers closer to the state of the art

Graduates $\rightarrow$ prepare $\rightarrow$ Graduates

young leaders
Next Steps

• Recruiting students
• NEET Workshops on:
  – Designing Projects
  – NEET Ways of Thinking
• Launching four threads this fall
• Other areas:
  – Program assessment
  – Governance
  – Recruiting instructors and academic staff
  – Fundraising
  – Cross-School initiatives
  – NEET Academy
• Thinking through our strategy for 2018-19
Thank you!

visit us at: neet.mit.edu

contact: neet@mit.edu