



**Massachusetts
Institute of
Technology**

A Curriculum that Meets the Customers' Needs

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5XME Objectives

. . . there's no doubt about it. Preparing the nation's engineers to be leaders in the 21st Century is vital to the nation's future.

A.Bement Jr., 5XME Workshop, 2007

We urgently need to identify the attributes that the mechanical engineering graduate in the USA must possess to compete successfully.

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5XME Workshop: Transforming Mechanical Engineering Education and Research in the USA, 2007.

Radical transformation will require radical actions!

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The meaning of terms

Who do we think of as a **leader**?

- Technical management leadership
- Functional leadership
- Entrepreneurial Leadership

Not expected to be a leader at age 22

Problem statement

We want to develop a curriculum that puts graduates on a trajectory to have **the required attributes to be leaders.**

We will proceed as if the curriculum were a product to be developed.

The customer for the product

Who is the customer for our new leadership curriculum?

Our Students are the Customers

Stakeholders include

- Employers
- Parents
- The Nation

The customer for the product

The Student is the Customer, but our customer doesn't know what s/he needs.

Our customer's needs are latent.

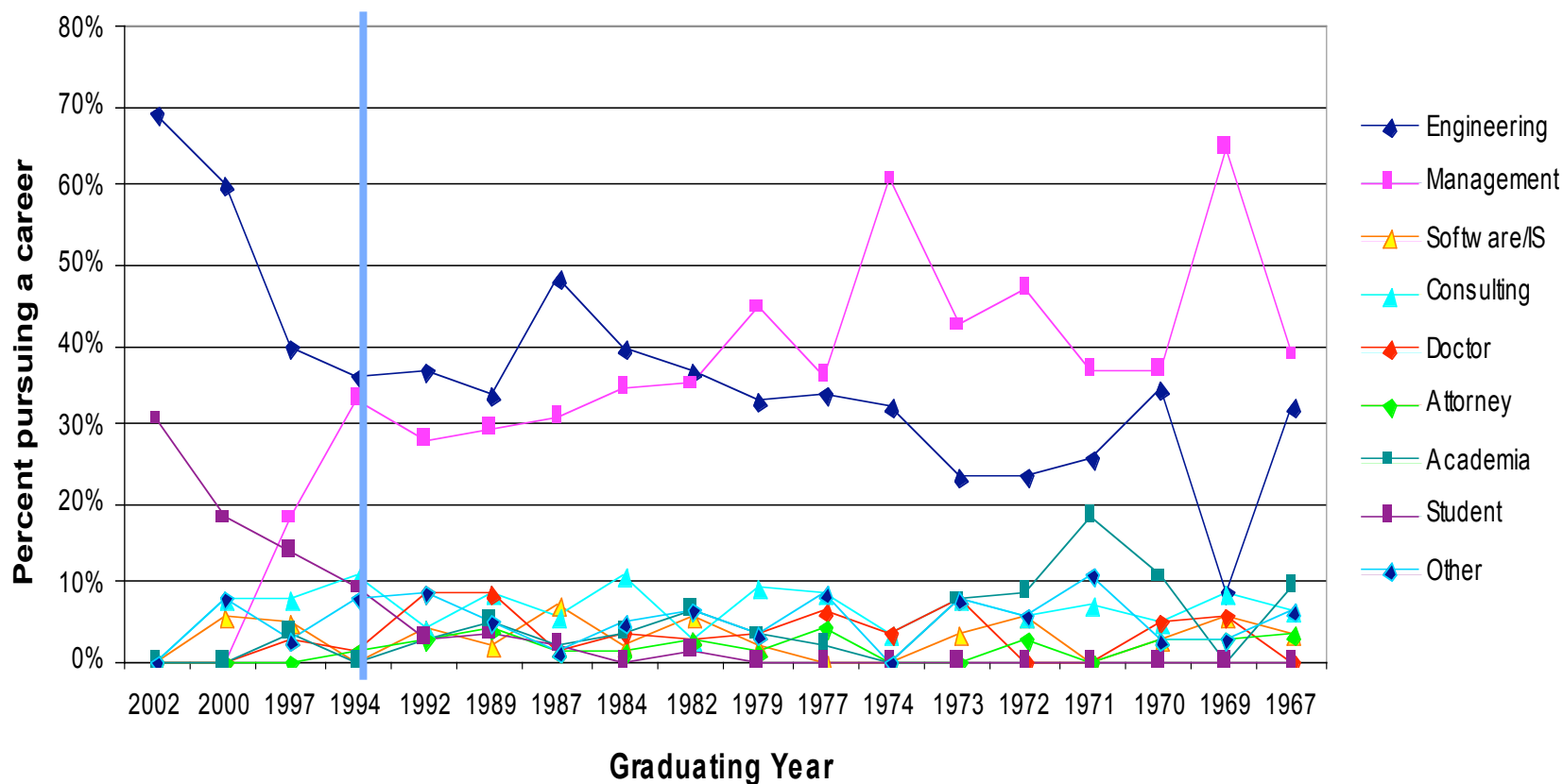
We will have to infer them.

Who is the Customer?

What do we know about the student customer?

A Customer Survey

Career Trends of MIT Mechanical Engineering Alumni



An assertion

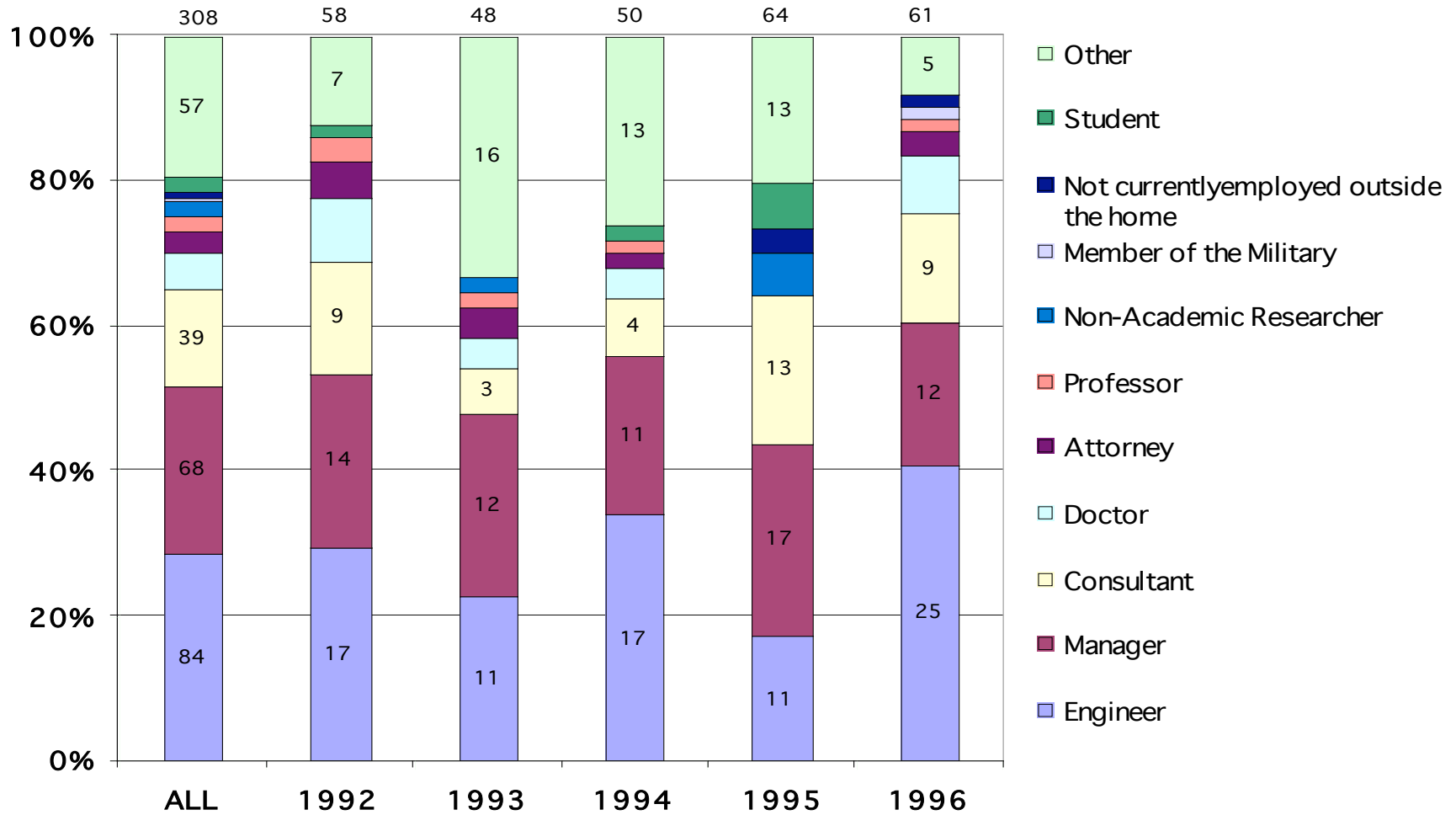
Our 30 year old alumni are surrogate customers for our curriculum.

A reformulation of the question

What **attributes** will our graduates need by age 30 in order to be prepared to accept **leadership responsibilities**?

We can ask them.

The Alumni Population



Knowledge

- Underlying Sciences
- Underlying Mathematics
- Mechanics of Solids
- Dynamics
- Thermodynamics
- Fluid Mechanics
- and so on

Skills

- Engineering Reasoning
- Systems Thinking
- Communications
- Teamwork
- Professional Skills
- Independent Thinking
- And so on

Frequency of Use

Frequency Scale

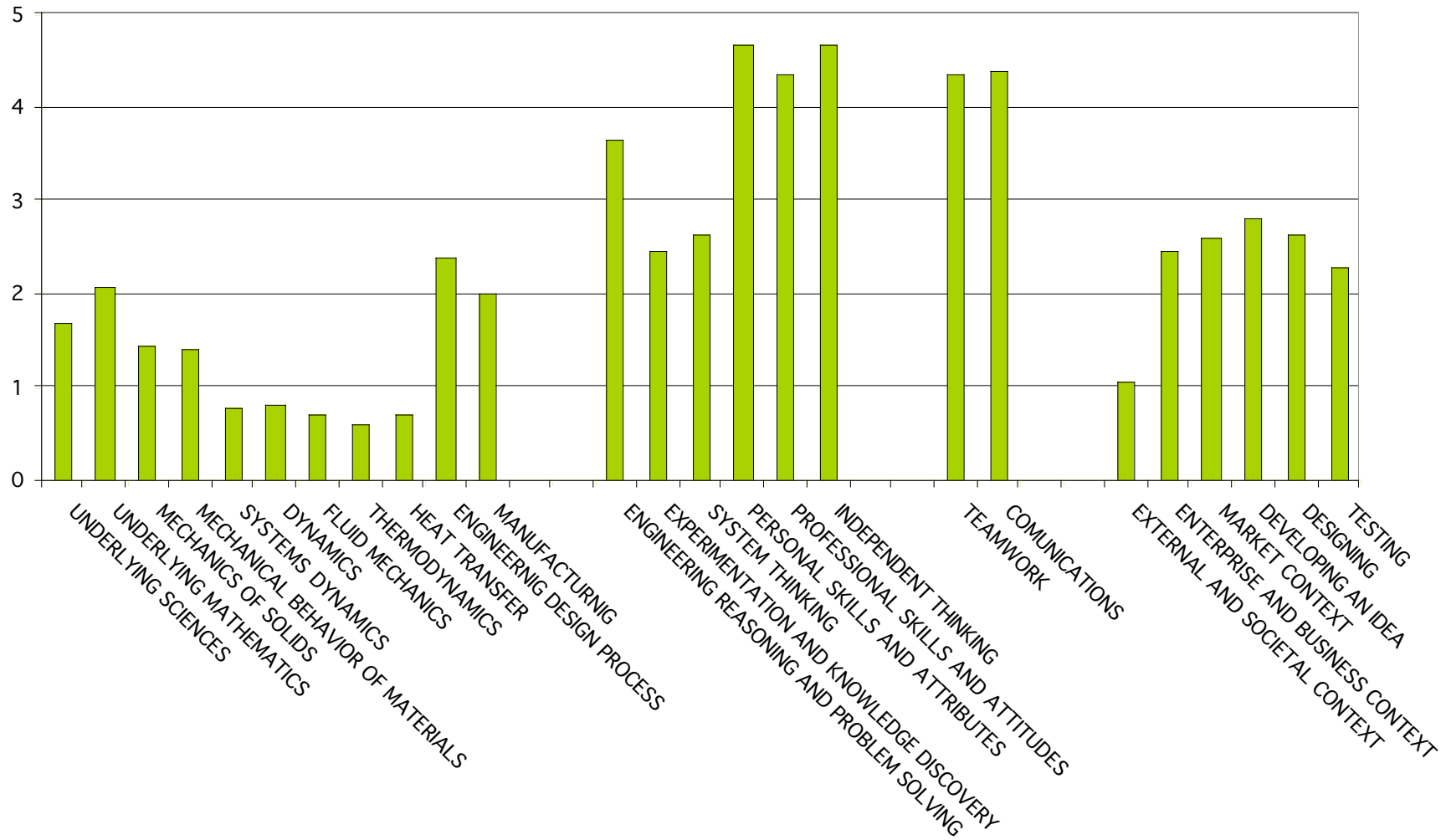
5. Pervasively, for almost everything I do
4. Frequently, on most days
3. Regularly, at least weekly
2. Occasionally, at least once a month
1. Hardly ever, a few times a year

Frequency of Use

Frequency Scale

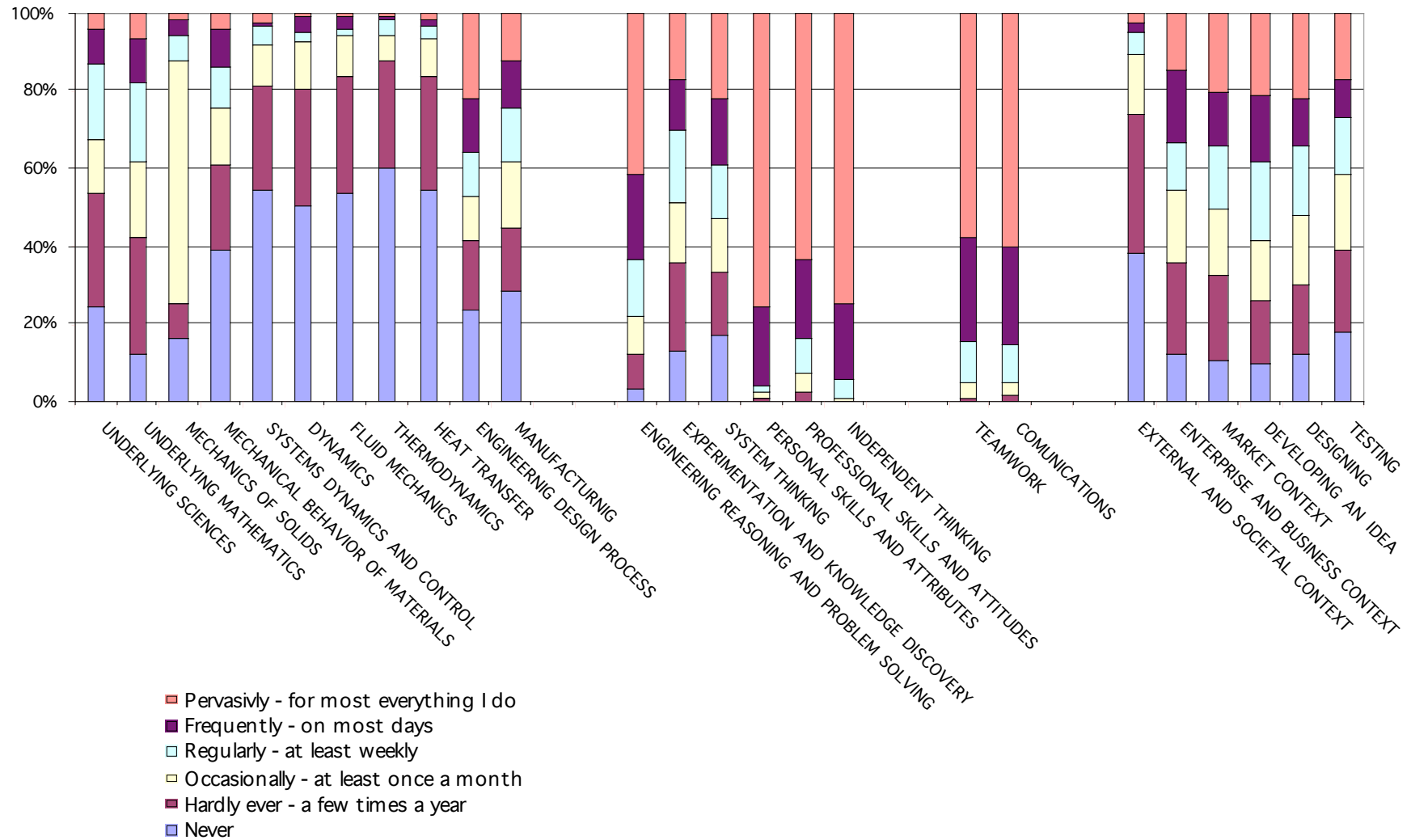
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0. Never

Mean frequency of use

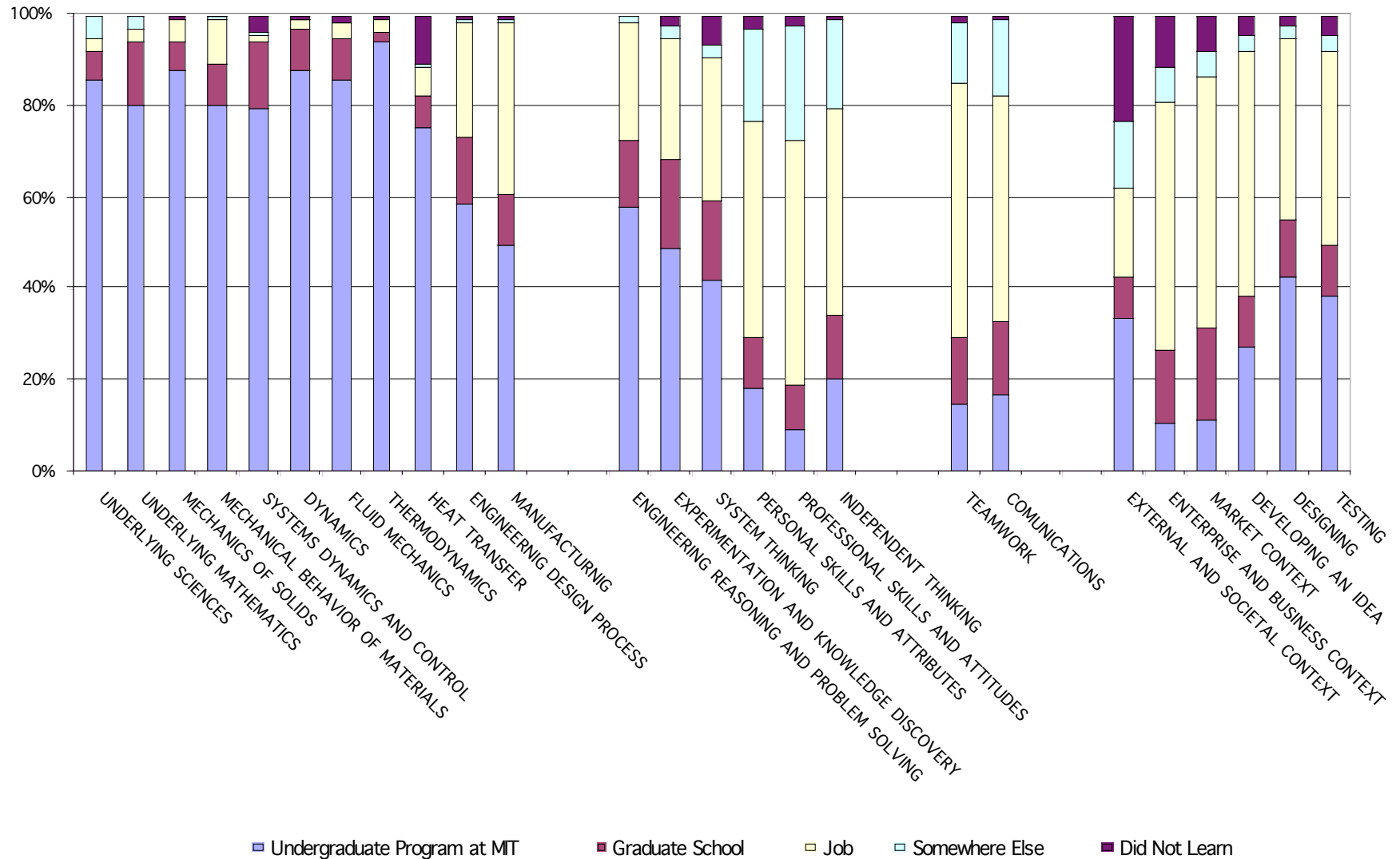


Frequency of Use: 0 Never, 1 Hardly ever - a few times a year, 2 Occasionally - at least once a month, 3 Regularly - at least weekly, 4 Frequently - on most days, 5 Pervasively - for most everything I do

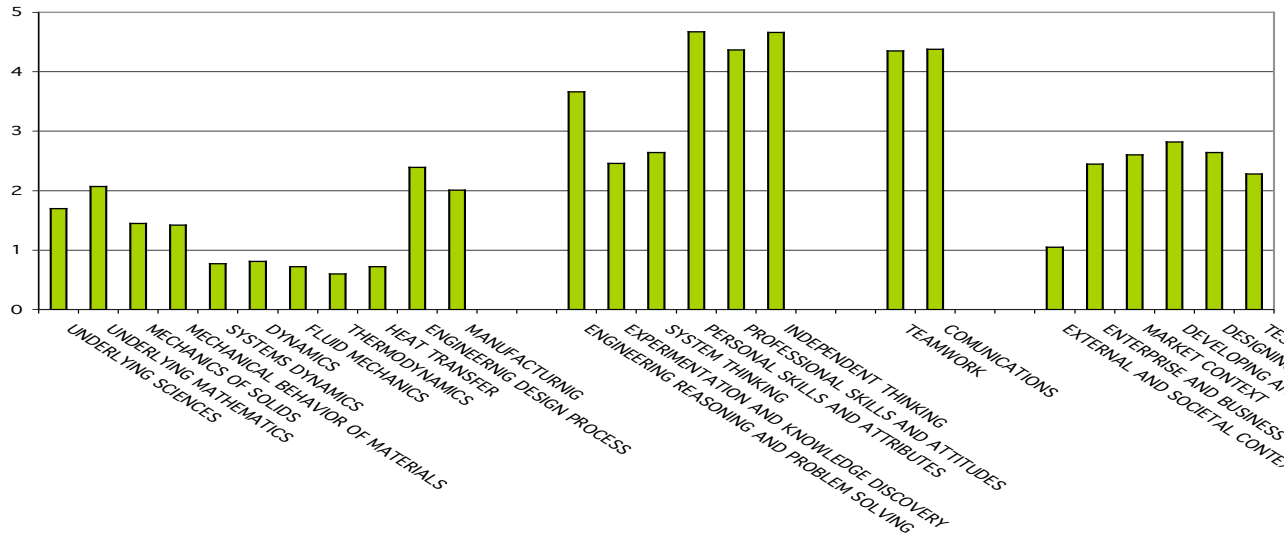
Frequency of use



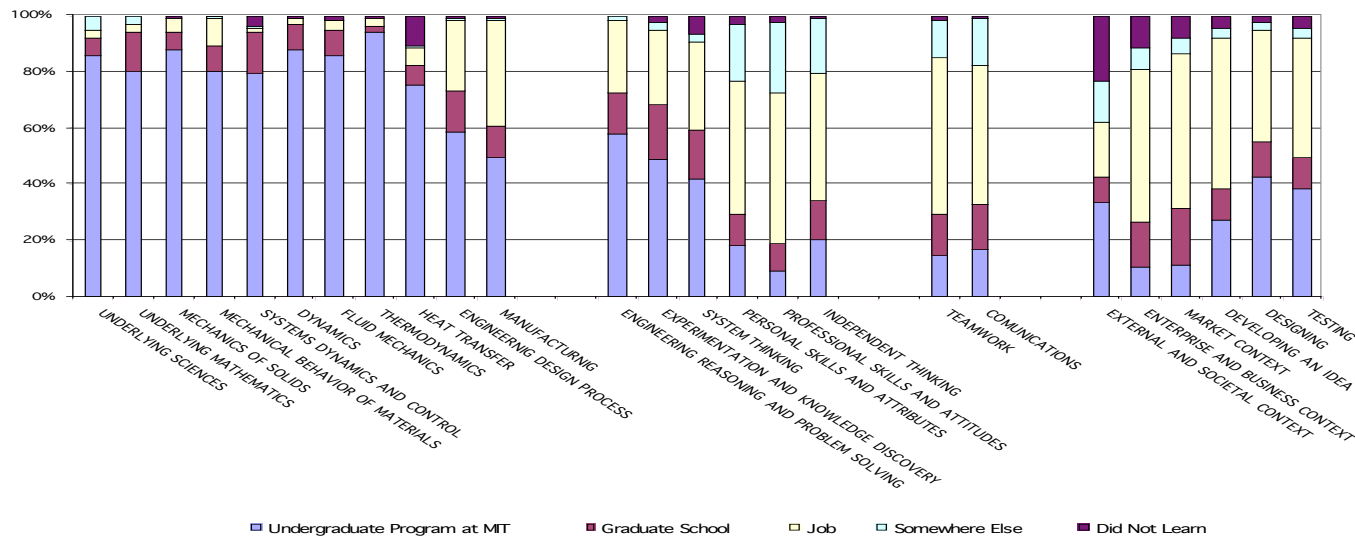
Source



Engineering reasoning and problem solving



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The problem

Our existing curriculum is not designed to deliver to our graduates the **attributes** that they will need **to be leaders** by age 30.

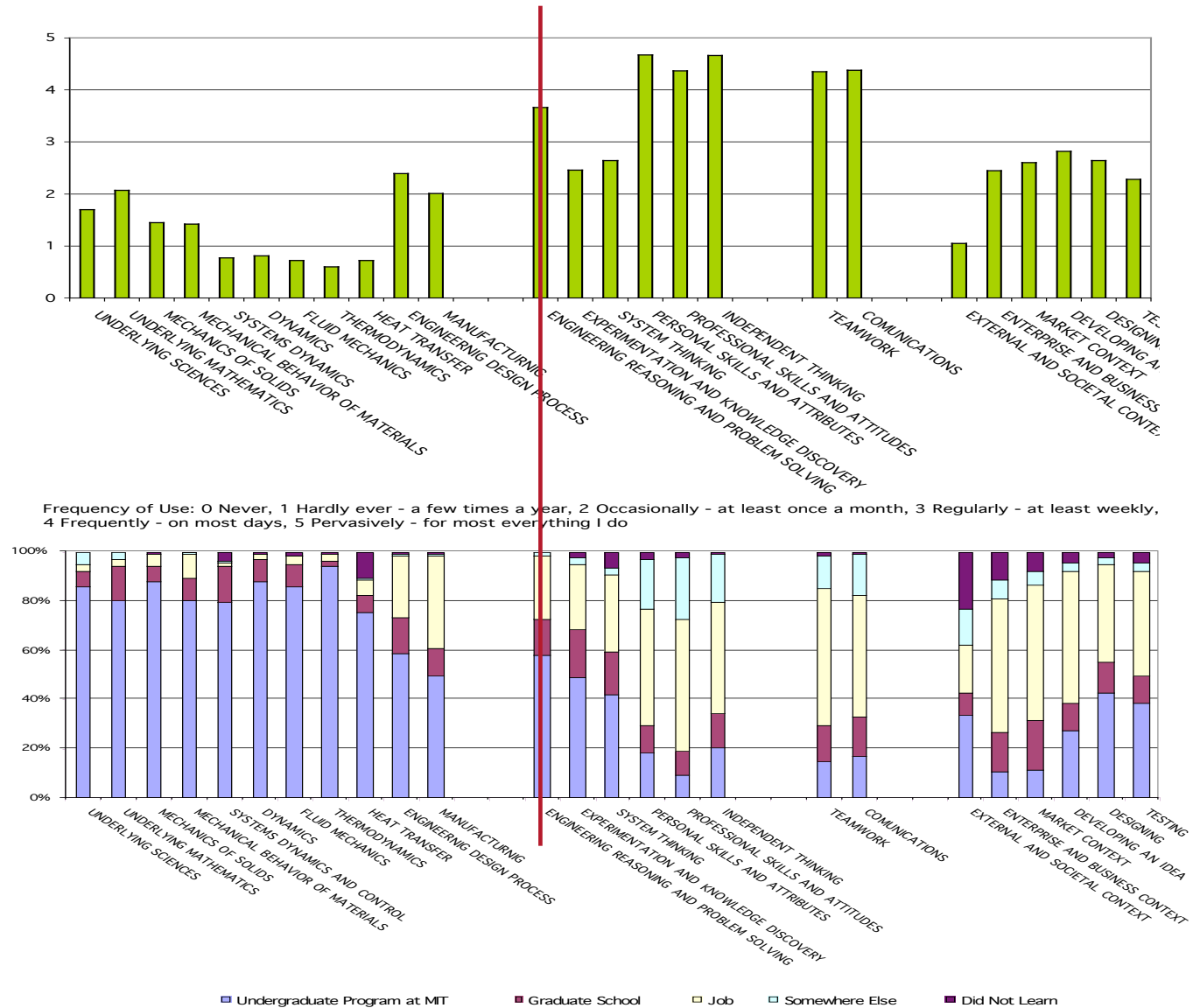
To the extent that they acquire these attributes, they do so in an unstructured manner on the job.

The 12-year curriculum

A Radical Action

Work closely with our industrial colleagues to develop a 12-year curriculum that will deliver to our graduates the **attributes** that they have told us will **prepare them for leadership positions** at age 30.

Frequency of use vs. Source



What do our customers need?

What can we learn about teaching engineering reasoning and problem solving skills?

More effective learning

- Worked with educational professionals
- 22 classroom experiments
 - Both qualitative and quantitative data gathered
- 36 participating faculty
 - Mostly from Mechanical Engineering
- 2000+ participating students
- More than 250 student interviews
- Four surveys
- Numerous focus groups
- Mining of alumni data

Participating faculty

From within the ME Department:

- Lallit Anand
- Mary Boyce
- Gang Chen
- Ernie Cravalho
- Dave Gossard
- Linda Griffith
- Pete Griffith
- Kim Hamad-Schifferli
- Nic Hadjiconstantinou
- Dave Hardt
- Doug Hart
- John Heywood
- Peko Hosoi
- Ian Hunter
- John Leonard
- Carol Livermore
- Gareth McKinley
- Bora Mikic
- Samir Nayfeh
- Dave Parks
- Daniela Pucci De Farias
- Ely Sachs
- Yang Shao-Horn
- Joe Smith
- Simona Socrate
- Todd Thorsen
- Dave Trumper

From outside the ME Department:

- Duane Boning
- Dave Darmofal
- John Deyst
- Haynes Miller
- Tom Roemer
- Gigliola Staffilani
- Sheila Widnall
- Karen Willcox

A recitation experiment in thermodynamics

Course 2.005, fall 2004

Ernie Cravalho, Linda Griffith, Yang Shao-Horn

A dedicated group of graduate students

Our objective was to mimic the Cambridge supervision system

A recitation experiment in thermodynamics

Course 2.005, fall 2004

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The semester was divided into three four-week chunks.

Each undergraduate student had eight normal recitation sessions and four small group supervision sessions.

In the final supervision session, each student was expected to present a solution to a problem and to defend the solution.

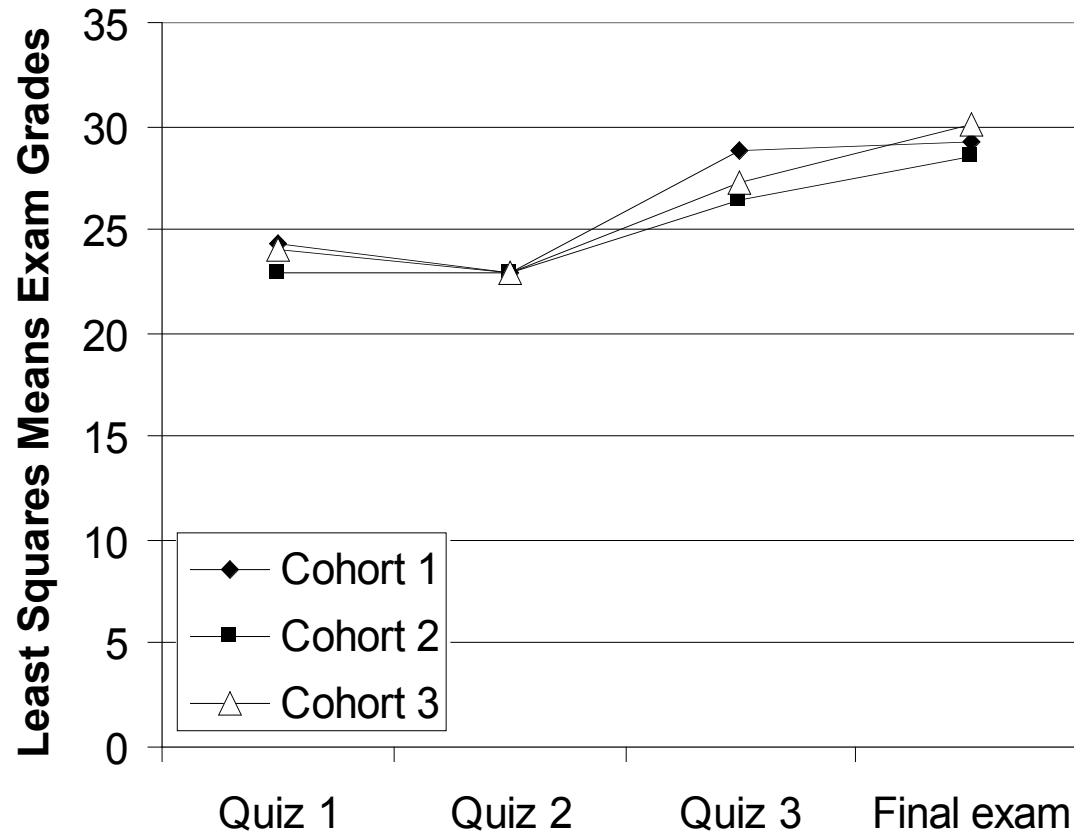
A recitation experiment in thermodynamics

- “The TA . . . was good at prompting us to answer questions but . . . didn’t tell us the answers. The TA made me think. Everything was so clear . . . It exceeded my expectations.”
- “I didn’t learn different things or more, I just learned better.”
- “...[the presentation] helped a lot because when you’re presenting to someone, you’re basically teaching them. . . . You see it, you do it and you teach it. . . . It went really, really well. The problem I had was similar to one of the ones on the test. To take the time to be able to explain it really, really helped me. It saved me on the test.”
- “It’s the best thing ever! Ideally, it’s how all engineering recitations should be.”

A recitation experiment in thermodynamics

- Participating faculty agreed that the students were demonstrating engineering reasoning and problem solving skills.

A recitation experiment in thermodynamics



Observations

- Students reported improvements in learning with almost every pedagogical treatment that we tried.
- The faculty also reported that the students were understanding the material better.
- Essentially none of the treatments yielded improved test performance.

Not a surprise to the students

- “Why would you think that it would affect our grades?”
- “Their grades would be identical. But the small group one would enjoy learning more and would be a better problem-solver in the long run. [The one attending the small group] would also be more likely to specialize in thermodynamics and fluid mechanics.”

Lessons learned

We and the students see things differently.

We are inclined to assume that the students will spend a certain amount of time on a given class. The better we teach, the more they learn.

From the students' perspective, the more effectively we teach, the less time they have to spend in our classes.

We and the students see things differently

In planning our classes, we assume that the students will remember what they've learned.

The students expect to forget much of what they learn, and they don't see it as a problem.

The two options ...

Results from the survey

Q3.	How much of the knowledge covered in your classes did you learn?
1	0-20%
2	21-40%
3	41-60%
4	61-80%
5	81-100%

Students 4.0

Faculty 3.3

Results from the survey

Q4.	How much of the knowledge that you learned do you remember now?
1	0-20%
2	21-40%
3	41-60%
4	61-80%
5	81-100%

Students 3.0

Faculty 2.4

The way the students see it

The students leave the university having learned only a fraction of what we have taught.

We have little control over what fraction they remember.

They are more likely to remember the course material if they take another course in the area.

The 12-year curriculum

A Second Radical Action

In the first few mechanical engineering classes, emphasize only the most fundamental knowledge, and measure to be sure that they learn it well enough to reason about it.

Use the time saved to teach leadership skills.

If and when they identify the topic that they wish to pursue, allow them to specialize.

Engineering educators are artisans practicing a craft.

The Engineering Code of Ethics states that
An engineer will never accept an assignment
for which s/he is not adequately prepared.

Three Radical Actions

1. Develop a 12-year curriculum that will prepare our graduates to accept leadership responsibilities by age 30.
2. Focus undergraduate learning on fundamental understanding. Measure outcomes. If/when students identify a concentration of choice, let them set aside elements of the core and specialize.
3. Exercise a high degree of professionalism when educating engineers.

1. Personal skills and attributes

Initiative and willingness to take risks

Perseverance and flexibility

Creative thinking

Time and resource management

2. Independent thinking

Skills in working independently

Skills in setting project goals

Ability to extract and evaluate relevant knowledge

Confidence in one's own skills and abilities

3. Professional skills and attitudes

Professional ethics, integrity

Responsibility and accountability

Professional behavior

Proactively planning for one's career

Continuous learning