The Future Forms of STEM Education

The future is already here

It’s just not evenly distributed yet

attributed to William Gibson
author of Neuromancer (1984)
What has changed/is new in knowledge of:
Technology
Pedagogy
Content (STEM discipline)
and in the intersection of these areas?

Evidence from research on learning and teaching in science and engineering suggests that a large part of the problem lies in the way these courses are traditionally taught:

—through lectures and reading assignments, note-taking and memorization, and laboratories with specific instructions and a predetermined result.

Lectures

.. in undergraduate STEM education, we have the curious situation that, although more effective teaching methods have been overwhelmingly demonstrated, most STEM courses are still taught by lectures

— the pedagogical equivalent of bloodletting


Lectures

The most fundamental problem of lectures is that they tend to be based on the information transmission fallacy.

This is the idea that what is taught by the teacher is remembered by the student. In reality however, students do not store information as taught.

Lectures and Notetaking

Typically fewer than 40% of the important lecture ideas are recorded.


Blended Learning - meta-analysis of research

Blended Learning outperforms fully face-to-face classroom instruction*.


*Conditions apply
Blended Learning - student satisfaction

Student satisfaction is greater in blended courses.*


The Flipped Classroom – Peer Instruction

Eric Mazur

https://youtu.be/FTIHMvMjU


The Flipped Classroom – Peer Instruction

.. overwhelmingly improves students’ problem solving abilities*


*Conditions apply

The Flipped Classroom

.. exam performance significantly improved *


*Conditions apply
Large-Enrollment Physics Class

**Control group**
- experienced lecturer.

**Experimental group**
- postdoctoral fellow
  - increased student attendance,
  - higher engagement,
  - and more than twice the learning*

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Teaching methods comparison in a large calculus class

.. we report improved student performance

— on conceptual items in particular

— with a switching replication in that each section outperformed the other on the topic for which it received the intervention

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Hawthorne Effect?


Lectures and Notetaking

.. the lecture theater is a good place to tell stories.

Finally, lectures have survived as a cost-effective way to instruct large numbers of students.

Types of Discipline Knowledge


Bloom’s (Revised) Taxonomy

Procedural and Conceptual Thinking in STEM

Tall, David. “The Theory Of Procepts.”

Engineering Maths 1 and 2

Khan Academy and similar sites – highest rated resource for study outside class.

A Conceptual Problem

2 people are in a canoe which is sitting in a swimming pool. They take a cannonball which is in the canoe and drop it into the pool. Does the water level in the swimming pool:

a) go up
b) go down
c) stay the same?


Procedural Knowledge (Instrumental Understanding)

Instrumental understanding in a mathematical situation consists of recognizing a task as one of a particular class for which one already knows a rule.

A Characterization of Calculus I Final Exams
(US Universities)

– focus on procedural fluency

the exams generally require low levels of cognitive demand, seldom contain problems stated in a real-world context, rarely elicit explanation, and do not require students to demonstrate or apply their understanding of the course’s central ideas.

Mathematics and Computers

Conrad Wolfram Ted Global 2010
http://www.ted.com/talks/conrad_wolfram_teaching_kids_real_math_with_computers?language=en#t-8582

Use computers for...

1. Posing the right questions
2. Real world → math formulation
3. Computation
4. Math formulation → real world, verification

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Mathematics and Computers

Use students for...

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Engineering Maths I

3. [15 marks] Evaluate the following integrals

(a) \( \int_{0}^{2} (\sqrt{x} + e^{2x}) \, dx \)
Mathematics Education

11. A water tank is in the form of a regular octagonal prism. The base octagon has side length 11.9 cm. The lateral edge of the water tank is 36 cm.

a) What is the surface area of the base?
b) What is the volume of the water tank?
c) If you pour water into the tank at a rate of 1.8 oz/sec., how long will it take you to fill the tank?

A ‘maths textbook’ problem – just find equations to fit and do the procedural calculations.

Dan Meyer TEDxNYED 2010
http://www.ted.com/talks/dan_meyer_math_curriculum_makeover

Mathematics Education

Real life exploration

Dan Meyer TEDxNYED 2010
http://www.ted.com/talks/dan_meyer_math_curriculum_makeover
Engineering Mathematics Education

Modelling using Tracker software

BYOD and Blended Classrooms

.. BYOD (Bring Your Own Device) and blended classrooms are beginning to become the norm in New Zealand schools.

NZQA 2013

computers are infrequently used during mathematics instruction.
Thinking in mathematics is inextricably interwoven with writing mathematics

Greiffenhagen, C. The materiality of mathematics: presenting mathematics at the blackboard. British Journal of Sociology

The cinematic art of teaching university mathematics: chalk talk as embodied practice
Fox, J & Artemeva, N

visual, spatial, and mathematical representations are essential tools for communicating and remembering ideas and solving problems.

Writing Sketching Thinking Communicating

in a digital environment?
Writing Sketching Thinking Communicating

in a digital environment?


Scientific Thinking and Representation

.. a pen interface stimulates people to write more nonlinguistic content (diagrams, symbols), compared with a keyboard interface or a non-digital pen.
Pen-Enabled Tablet PC Environment

The Flipped Classroom

Traditional
- Presentation of content material in class
- Problem solving outside class - homework

Flipped
- Presentation of material outside class
- Problem solving in class with peers

https://youtu.be/FUY049rIjdM
Why not just read a text book?

Lacks dynamic procedural development

Worked Examples and Screencasts

EXAMPLECASTS: THE UNREASONABLE EFFECTIVENESS OF WEBCAST WORKED EXAMPLES IN INTRODUCTORY UNIVERSITY PHYSICS

Paul Francis

Engineering Maths 1 and 2

Khan Academy (& similar external resources) the highest rated resource by AUT Eng Maths Students

Change
Barriers to Change

... lectures have survived as a cost-effective way to instruct large numbers of students.


Barriers to Change

Your views???
Barriers to Change

expectations of content coverage, limited instructor time for multiple responsibilities, lack of training and curriculum materials, departmental norms, student resistance, class size and room layout, time structure, fiscal resources, appropriate facilities, and institutional reward structures and culture, particularly research priorities.


Barriers to Change

More specifically, by tending to favor research over teaching, systems and reward structures promote the status quo in teaching and curriculum.

Recommendations for Change

For example, deans and departments should:

• Find ways to diffuse innovations to faculty members in other departments who teach engineering students. (Lattuca, 2011; Merton et al., 2001)
• Provide opportunities for graduate students to learn about innovative teaching methods (supervised and mentored teaching and reflection opportunities) and hire graduates with a record of interest in teaching and curriculum development. (Lattuca, 2011; Lattuca & Stark, 2009)
• Provide professional development opportunities for faculty to learn about teaching, curriculum design, and student learning by means of teaching and learning centers and workshops (Lattuca & Stark, 2009) and continuous discussion, evaluation, and assessment of curricula, teaching, and learning. (Lattuca & Stark, 2009; Merton et al., 2001)
• Reward faculty who have made improvements in teaching and learning and remove disincentives for trying; establish official criteria that value and reward teaching, both monetarily and in tenure and promotion. (Lattuci & Stark, 2009; Merton et al., 2001)
• Create new structures, positions, and policies to accommodate innovations. (Lattuca & stark, 2009)
• Give faculty extra time such as release time or extensions on the tenure and promotion period to try new methods. (Seymour et al., 2011)
• Engage senior colleagues with power and influence in the change process. (Mertonet al., 2001; Seymour et al., 2011)
• Offer faculty easily accessible and useful resources for implementing teaching innovations. (Lattuca & Stark, 2009; Seymour et al., 2011)

Barriers to Change

“Culture eats strategy for breakfast.”

(attributed to) Peter Drucker

Lukasz Kawilski, CIO of the New Zealand Qualifications Authority (NZQA).

Radical innovation and the challenge of socio-technical transitions


Lecture-Based vs Challenge-Based Learning at Boeing

Challenge based learning showed:

• More interaction and sharing of knowledge
• Better integration and synthesis of concepts

Change

System issues

account for most problems and possibilities for improvement.

W. Edwards Deming


St Paul St Precinct

“The new building will include

....... collaborative
social learning spaces

"design ... informed by thorough research into the campuses at future-focused universities like Queensland University of Technology and RMIT"
Academic development for learning spaces

http://www.aut.ac.nz/study-at-aut/campuses/current-campus-updates
St Paul St Precinct

“... will lead the way for greater collaboration and faster adoption of new technologies.”


St Paul St Precinct

While universities are enthusiastic about building new student-centred and technology-enriched learning spaces, there is less emphasis on how teachers are helped to re-conceptualise their learning designs for these spaces.”

few have had the opportunity to re-conceptualise the teaching of their discipline within this environment. It is imperative to provide both timely and targeted professional development and explore with academics how these environments can be used to capitalise on new pedagogies, digital technologies and sustainable learning designs.


RMIT University has made significant investments in next generation learning spaces in the past with over 90 new or refurbished spaces. However, the teaching and learning possibilities that Next Generation Learning Spaces promise have not, on the whole, been exploited. There are many reasons for this lack of take up. Many academics have not been introduced to the space, the technology that it offers, or its potential for different approaches to teaching and learning.

What will the future of STEM Education look like?