

Innovation in STEM teaching: Macquarie University Science and Engineering

ASSOC PROF JAMES DOWNES

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Context

NEW SOUTH WALES (NSW), AUSTRALIA

- Decreasing number of students selecting Science subjects in Y11 + Y12
- Strong decline in students selecting higher Mathematics in Y11 + 12
- Partially driven by high schools - high schools are ranked on their performance
- Perception that students will 'do better' in lower-level (non-calculus) mathematics
- Results in under-prepared students wishing to do science and engineering at university
- In turn results in the perception that university science and engineering is too difficult
- National perception that this is 'caused' by science and mathematics teachers who are not directly qualified in this specialization

NATIONAL EDUCATION

HSC students abandoning high-level subjects

By Pallavi Singhal

24 March 2018 – 12:05am



The proportion of students doing high-level maths and science subjects in the HSC declined over the past 10 years along with Australia's performance in international experts say is linked to the country's attitudes towards STEM.

Only 4.18 per cent of HSC students did Maths Extension 2, the highest level maths available, last year. This was down from 4.58 per cent of the cohort in 2007.

Only 11.54 per cent of year 12 students did Maths Extension 1 in 2017, down from 2007, and 22.36 per cent studied Mathematics, down from 26.99 per cent.



Australian Government position

THE STEM SHORTAGE

- Government perceives that there is a worsening shortage of STEM qualified graduates
- Projection is that will reach crisis point in some areas shortly e.g. Information Technology
- Solution is to force all teacher trainees to pass a threshold mathematics test
- And.... nothing...
- This is a difficult problem

Deloitte Access Economics

Australia's STEM
workforce: a survey
of employers



Macquarie University experience

SCIENCE AND ENGINEERING

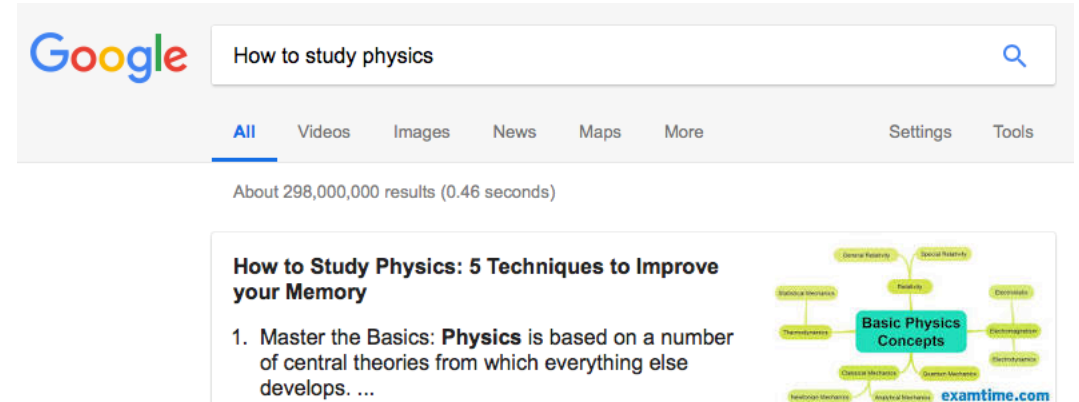
- 25% of incoming students who are interested in engineering do not have sufficient skill in mathematics (calculus) to succeed in first-year
- In many areas of science the majority of students do not understand calculus – affects success in studies
- Decline in learning engagement and class attendance
- Students live in a ‘media consumption environment’ – they “will watch the class later” but lack the motivation to do so
- Failure rates steadily increasing
- Retention rates decreasing – students are frustrated and drop out



What is the real issue?

WHAT IS LEARNING IN STEM?

- Access to STEM knowledge was, until recently, quite restricted, e.g. textbook or access to an expert
- Learning historically involved study of ‘restricted knowledge’, e.g. ‘physics’
- It was perceived that attainment of this knowledge was the learning.... but it is not!
- Learning is the development of a skill in a new area - learning changes the way that we think about the world around us
- Current students appear to perceive that access to knowledge is the same as learning a skill, but clearly this is not the case



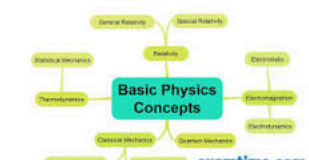
Google How to study physics

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About 298,000,000 results (0.46 seconds)

How to Study Physics: 5 Techniques to Improve your Memory

1. Master the Basics: **Physics** is based on a number of central theories from which everything else develops. ...



The mind map diagram shows 'Basic Physics Concepts' at the center, with branches to 'General Relativity', 'Special Relativity', 'Thermodynamics', 'Electromagnetism', 'Classical Mechanics', 'Quantum Mechanics', 'Statistical Mechanics', and 'Electrodynamics'. The source 'examtime.com' is noted at the bottom right.



Student environment

HOW DO WE FEED INTO THIS PERCEPTION?

- Historically we have:
 - Restricted access to knowledge
 - Taught knowledge in the classroom
 - Assessed students based on their knowledge (or at least given this impression)
 - Certified the attainment of knowledge at the end of a program, e.g. BSc(Physics)

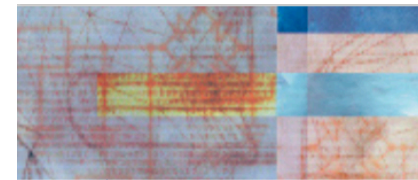
But is that what we actually want?



Employability / enterprise skills

SKILLS BASED TEACHING

- Interestingly... we are able to easily convince students that they will need a set of skills to gain and hold a job
- This leads to the idea of a set of skills, called 'employability' or 'enterprise' skills:
 - Complex problem-solving
 - Critical Thinking
 - Creativity
 - People Management
 - Coordinating with others
 - Entrepreneurial thinking
 - Emotional intelligence
 - Judgement and decision-making
 - Service orientation
 - Negotiation
 - Cognitive flexibility
- Combined with discipline skills, this is what employers want.



LEADERSHIP [Views from the Top]

The Role of Higher Education in the Changing World of Work

The changing world is a universal topic of interest, with particular resonance to higher education. Colleges and universities research change, teach about change, and often impact current and future change. To support students to live in this

■ Employers expect the graduate and new hire to have refined and agile communication skills needed successfully in an organizational context with a variety of stakeholders. They expect the hire to be able to navigate the perspectives of these various stakeholders.

MQ STEM teaching experiments

STEM SKILLS IN A TERTIARY ENVIRONMENT

In a tertiary environment we have great flexibility in how we teach... we can try (ethical) experiments.

Recent and planned experiments:

- Participation and Community Engagement (PACE)
- Research-integrated teaching
- Problem-based learning in Engineering
- Employability / enterprise skills in Science

PACE experience

EXPERIENCE

Practical experience ▾

[PACE experience](#)

What can I do?

Home EXPERIENCE Practical experience

Macquarie's multi award-winning PACE (I program engages you in real world learning Australia and around the globe. Through

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PACE – work-integrated learning

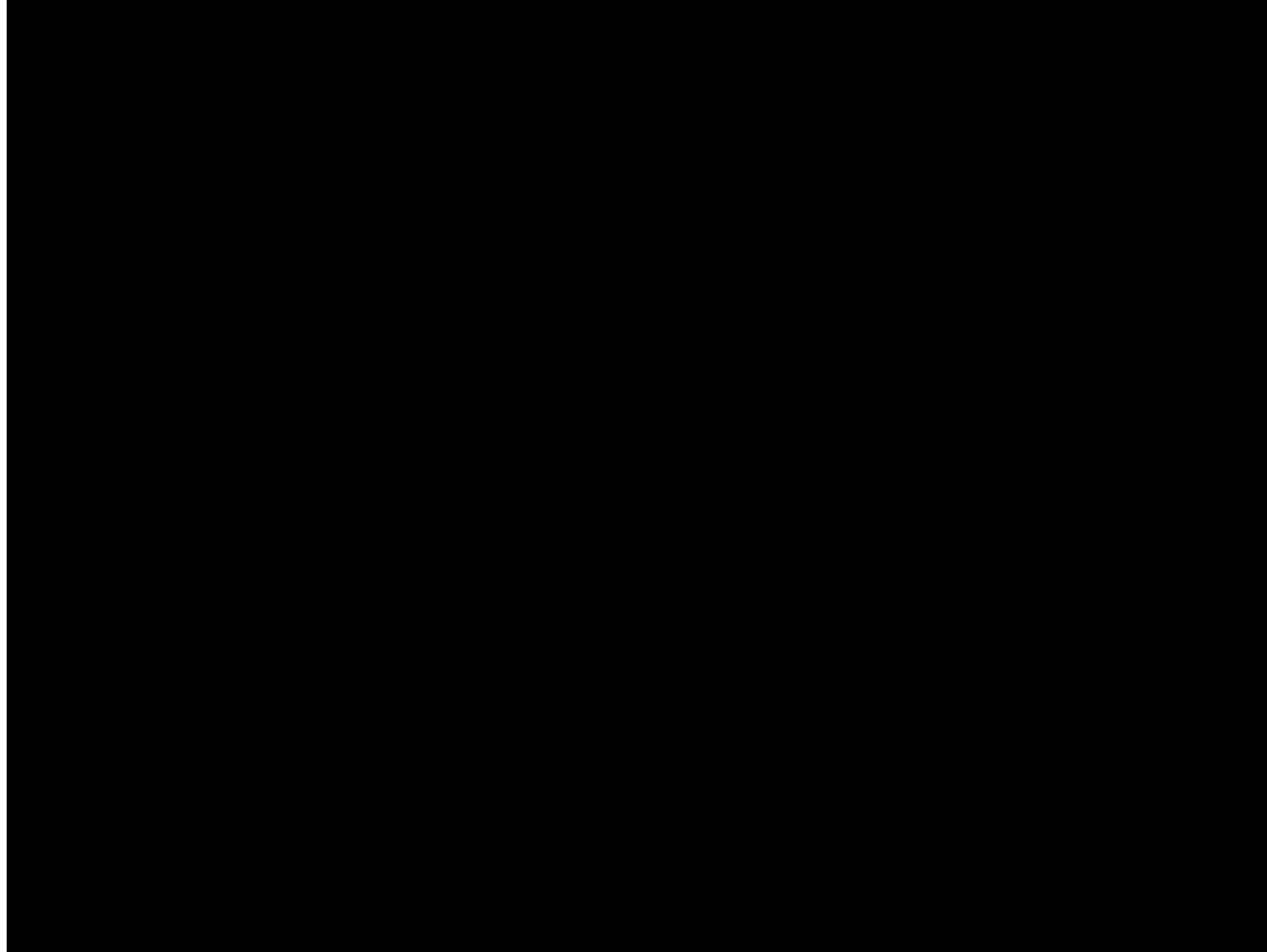
INTEGRATED COMPULSORY INTERNSHIP

- All Macquarie University undergraduate students are required to complete a PACE class – work-integrated learning
- 35 hours of preparation work e.g. expectations in the workplace, social interaction in the workplace, hierarchy etc.
- 70 hours placed in a company, non-government organization, government department, research laboratory etc.
- 35 hours of debrief and reflection on their experience e.g. report on findings for their company supervisor + report for academic supervisor reflecting on their learning and skill attainment in the company environment
- Typically organized by a dedicated team in the Faculty, although students can organize their own
- For Macquarie Science and Engineering approx. 800 placements per year, in 160+ partner organizations



PACE STEM experience

STUDENT VOICE



The PACE issue...

TOO LATE....

- The PACE program is very popular
- Many students take a second PACE class as an elective
- Students report that the PACE program completely changes the way they think about their studies

Why?

- They see the discipline skills that they have learned in classroom put into action, towards a cause
- They use and observe their own non-discipline skills in the workplace, with encouragement from working experts (who are not their teachers!)

So what do students and staff report as the problem with PACE?



STEM employability integration

EXPANDING PACE TO THE WHOLE DEGREE

- PACE students comment that they wish they had the employability experience earlier in their program...
- > Build employability / enterprise skills development into all 55 Science and Engineering programs
- Primary goal is to increase engagement
 - Complex problem-solving
 - Critical Thinking
 - Creativity
 - People Management
 - Coordinating with others
 - Entrepreneurial thinking
 - Emotional intelligence
 - Judgement and decision-making
 - Service orientation
 - Negotiation
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Employability structure - BSc

FOUNDATION CLASSES

- Take employability skills work from 3rd year PACE class, move to 1st year
 - Combine with foundational mathematics, statistics, and computing skills work
- > Create three Foundation classes:

Foundation Mathematics

Core mathematics skills for all science students

Scientific computing

Core data manipulation and management skills

Foundation Statistics

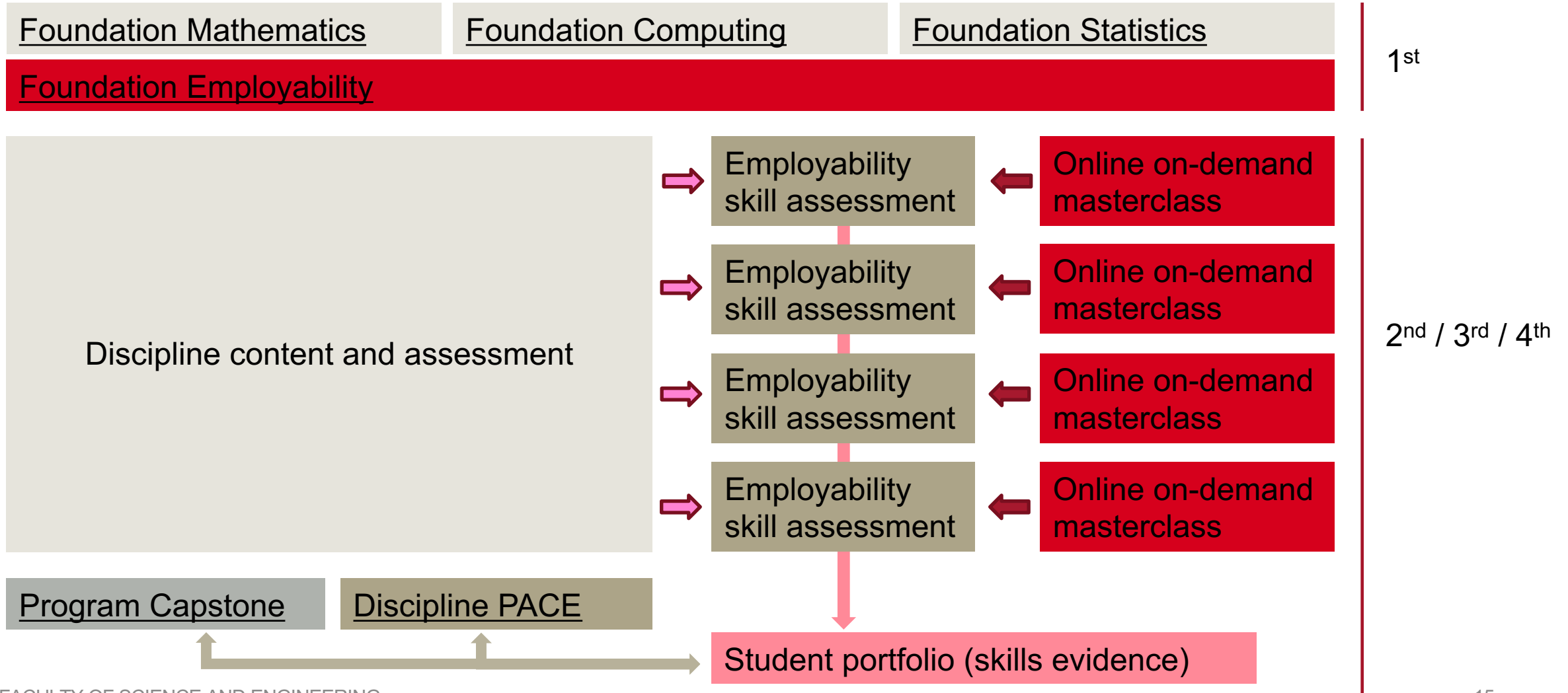
Core statistical analysis skills for all science students

Foundation Employability

- Introduction to employability skills concepts and their use in their discipline program
- Training in online portfolio software and portfolio creation and maintenance
- Participation in an on-campus industry employment fair

Employability structure

MASTERCLASSES AND DISCIPLINE ASSESSMENT



Employability structure

ENHANCED CAPSTONE AND PACE

- Near the end of their programs, students will have a portfolio of documented skills development and a good understanding of employability skills
- PACE classes + internships will now be strongly enhanced, both for the student and industry partner
- Capstone classes will take documented discipline and employability skill development and help students:
 - Understand the overall structure of their discipline content
 - Understand their personal skill development, personal key attributes
 - Learn how to demonstrate these skills to others (employers)



Employability skills in Science

- Teach students how to learn in a tertiary environment
- Alongside discipline skills, build student soft / employability skills
- Students maintain a portfolio to document their skill development
- Provide students with a authentic placement experience
- Teach students how to present their true skill attainment to a prospective employer
- 2020 – the experiment begins



Questions?

james.downes@mq.edu.au