Enterprise Education for Engineers with the Technology Evaluation and Commercialisation Framework

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(1). Background and context for engineering education, enterprise and entrepreneurship

Taking a broader view of enterprise and entrepreneurship

- **Enterprise** is defined as the generation and application of ideas, which are set within practical situations during a project or undertaking.

- **Entrepreneurship** is defined as the application of enterprise behaviours, attributes and competencies into the creation of cultural, social or economic value. This can, but does not exclusively, lead to venture creation.

Reference: Quality Assurance Agency (QAA) (2018). *Enterprise and entrepreneurship education: guidance for UK higher education providers* https://www.qaa.ac.uk/docs/qaas/enhancement-and-development/enterprise-and-entrpreneurship-education-2018.pdf?sfvrsn=15f1f981_8

"A startup is a human institution designed to create a new product or service under conditions of extreme uncertainty"

Ries, E. (2011). *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses*. Crown Books.

Need for enterprise education

"All university students should have access to enterprise and entrepreneurship, including a growing ambition amongst young people to develop their interest in social enterprise. In higher education, enterprise should extend to all areas of faculty and study, and I am encouraging universities to have an elective enterprise module available to all students."

Higher Education Academy. Enhancing employability through enterprise education: Examples of good practice in higher education, November 2014

Originally from: Lord Young Report (2014) Enterprise for all: the relevance of enterprise in education

https://www.heacademy.ac.uk/system/files/resources/enhancing_employability_through_enterprise_education_good_practice_guide.pdf

Need for entrepreneurship education

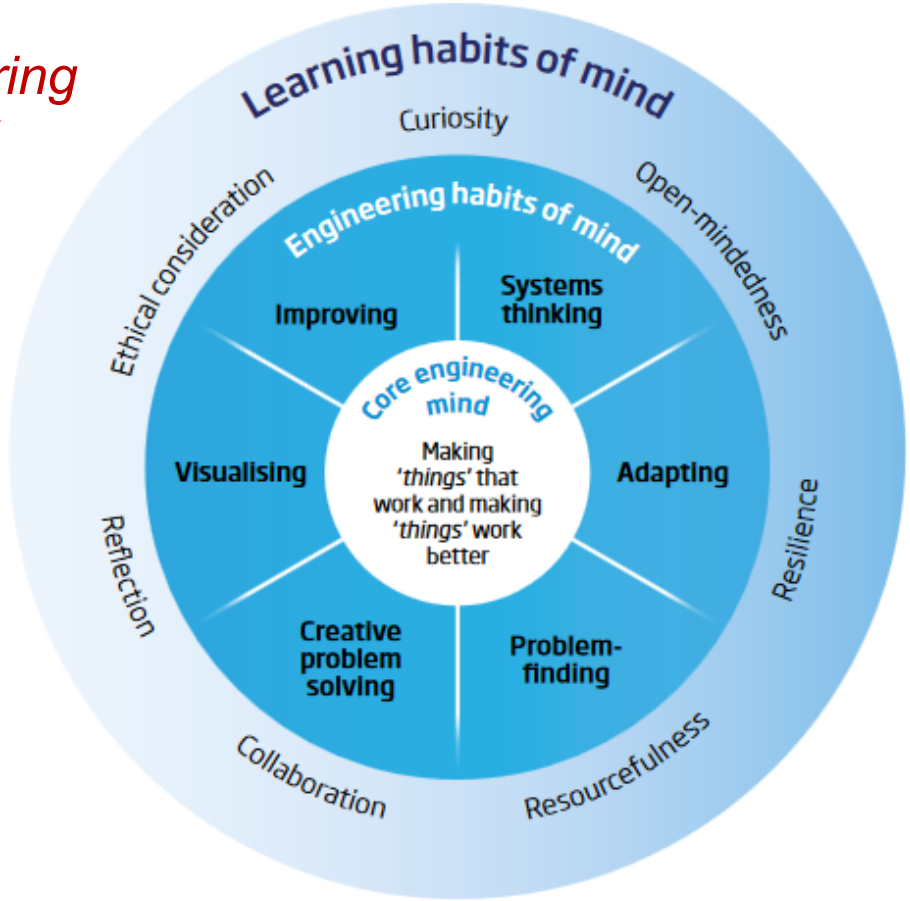
"Entrepreneurship education should also enable individuals to develop the transferable skills that will help them to adapt to future work and career changes. Such entrepreneurial and business skills training should also be available for academic staff".

RAE (2017). *Engineering an economy that works for all*. Report by the Royal Academy of Engineering (RAE)

https://www.raeng.org.uk/publications/responses/engineering-an-economy-that-works-for-all

Perspectives on engineering education and graduate employment

Engineering habits of the mind



Source: Learning to be an engineer: Implications for the education system, Royal Academy of Engineering, 2017

- EngineeringUK estimates that the country needs **over 1.2 million more engineers and technicians between 2014 and 2024**, including annually:
  - 124,000 engineers and technicians with 'core engineering skills' required to 2024
  - 79,000 people with 'mixed application of engineering knowledge' alongside other skill sets required to 2024
- ***"There are global challenges ahead. To address them, we need an increased skills base and an abundance of innovation and creativity"*** – Report quote by Professor Juergen Maier, CEO Siemens UK

Source: Improving employment opportunities for diverse engineering graduates, Royal Academy of Engineering, 2018

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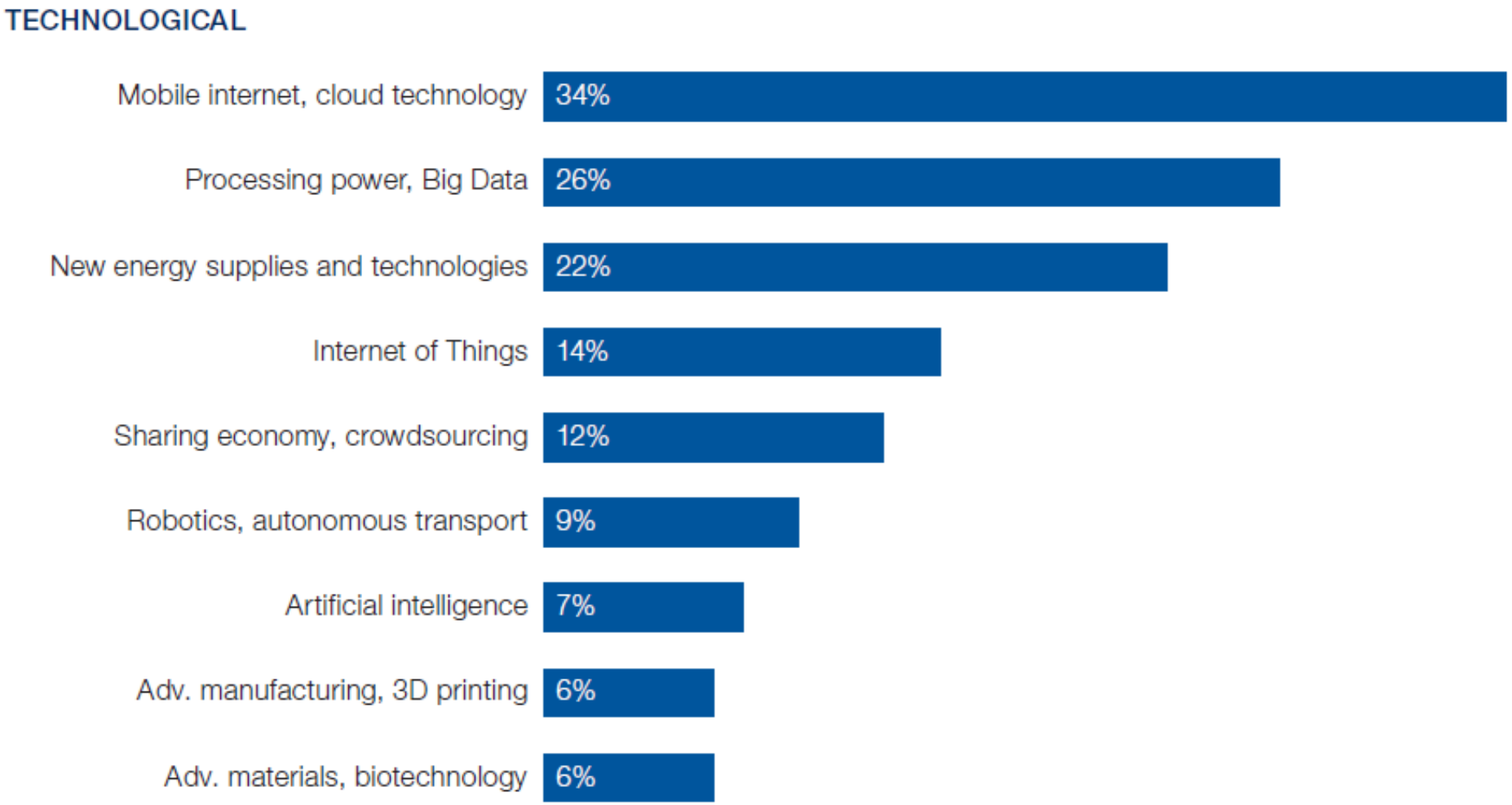
Global employment trends – Drivers of change

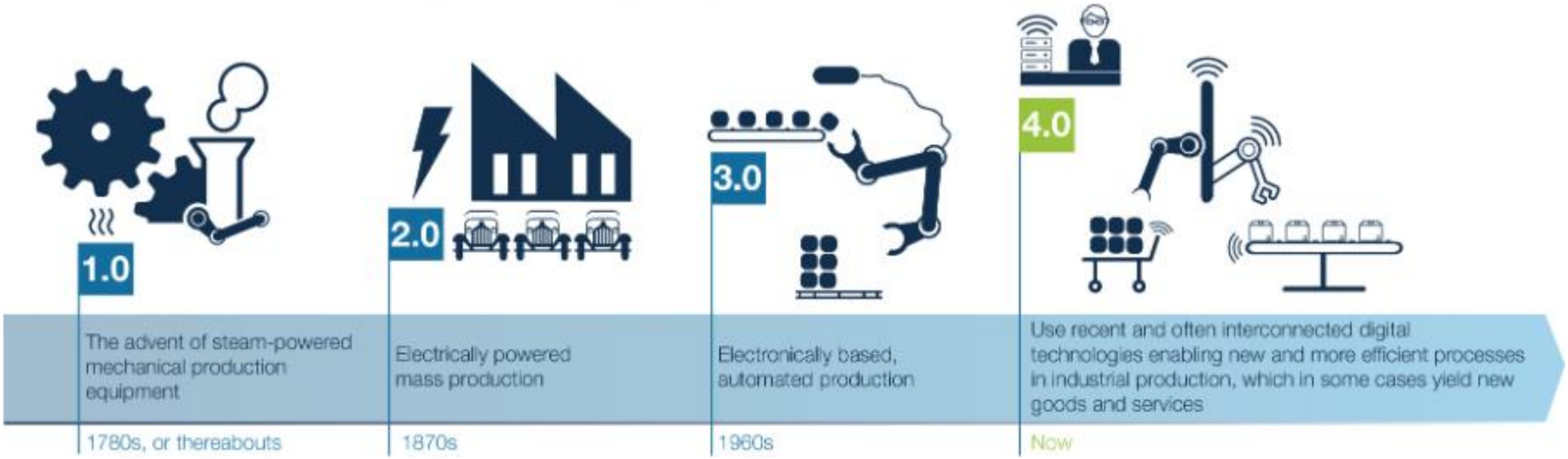
The Future of Jobs Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution

World Economic Forum Report (2016)



http://www3.weforum.org/docs/WEF_FOJ_Executive_Summary_Jobs.pdf

Industrial Revolutions and Industry 4.0



https://www.oecd.org/innovation/the-next-production-revolution-9789264271036-en.htm

Comments on the strategic context

- Employers increasingly require graduates to possess a range of professional related skills in addition to discipline specific knowledge, including the ability to be innovative, creative and have an enterprising mind-set. In this context, enterprise education can be linked to improving employability for graduates

- The Royal Academy of Engineering has identified that engineering students need to be exposed to industrial applications of engineering and acquire basic skills associated with business management and entrepreneurship

- In terms of global trends, the nature of work appears to be changing and there are a range of digital technologies making an impact – combined with the emergence of Industry 4.0 this leads to many challenges and opportunities for engineers

- It is important for engineers to be enterprising and gaining an understanding of technology evaluation and commercialisation supports this objective

(2). Technology evaluation and commercialisation (TEC) module

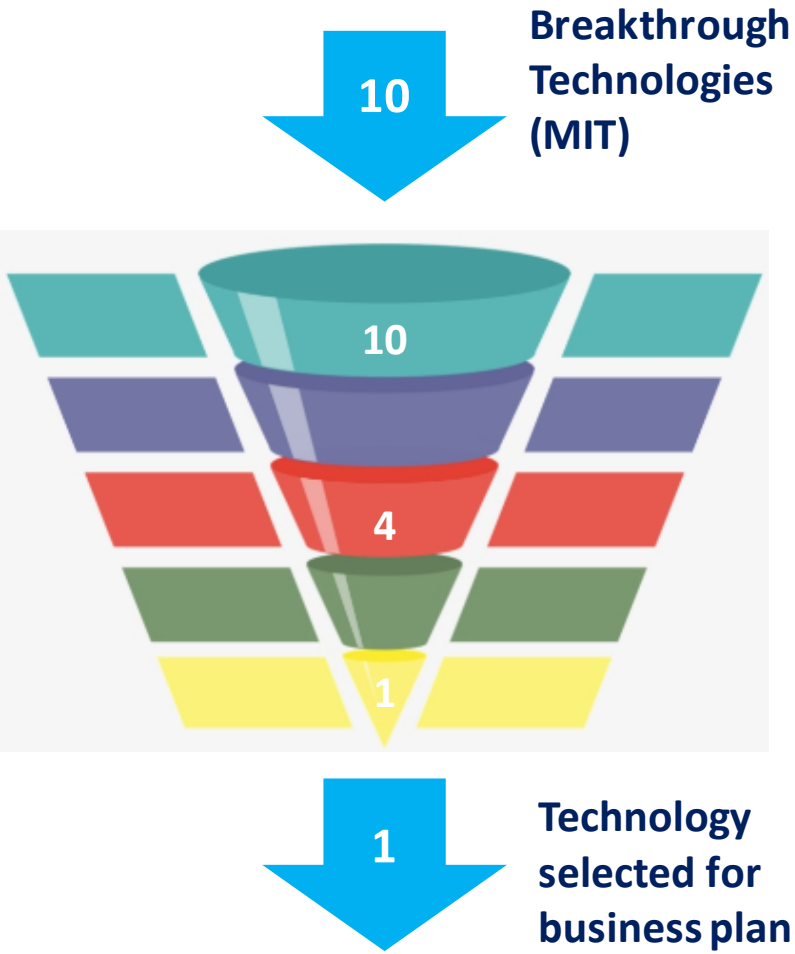
Introduction to the TEC module

- The Technology Evaluation and Commercialisation (TEC) module involves use of the TEC Algorithm that was originally developed at North Carolina State University (USA)

- The TEC module allows postgraduate Masters' level students to be guided towards identifying an emerging technology idea that is evaluated for its commercial potential. The module is a highly 'experiential learning experience'

- Detailed research and analysis is conducted according to a prescribed algorithmic model in order to evaluate the business potential of the technology

- This approach allows the students to prepare the commercialisation strategy and write the business plan for a potential high-tech start-up company



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Learning outcomes for the module - 1

1) Knowledge and understanding

- To use the tools, methods and processes of the algorithmic approach to assess the commercial potential of innovative products within a selected technology, assess and evaluate technology's unique advantages.
- Formulate appropriate product concepts, features, attributes, and benefits.
- Research and evaluate product markets. Produce a Business plan for your high technology enterprise.

Learning outcomes

Learning outcomes for the module - 2

2) Intellectual skills

- To be able to recognise the innovation process and its impact on enterprise and apply a systematic process to evaluate a selection of technologies for their commercialisation potential.

3) Practical skills

- Perform basic technical, organisational, legal, financial, market, and operational assessments. Define and adhere to appropriate decision-making criteria.

4) Transferable skills

- To effectively communicate and critically evaluate observed results in a technical format, analyse the business potential of high technology projects using a systematic approach and contribute and work as part of a team.

Learning outcomes

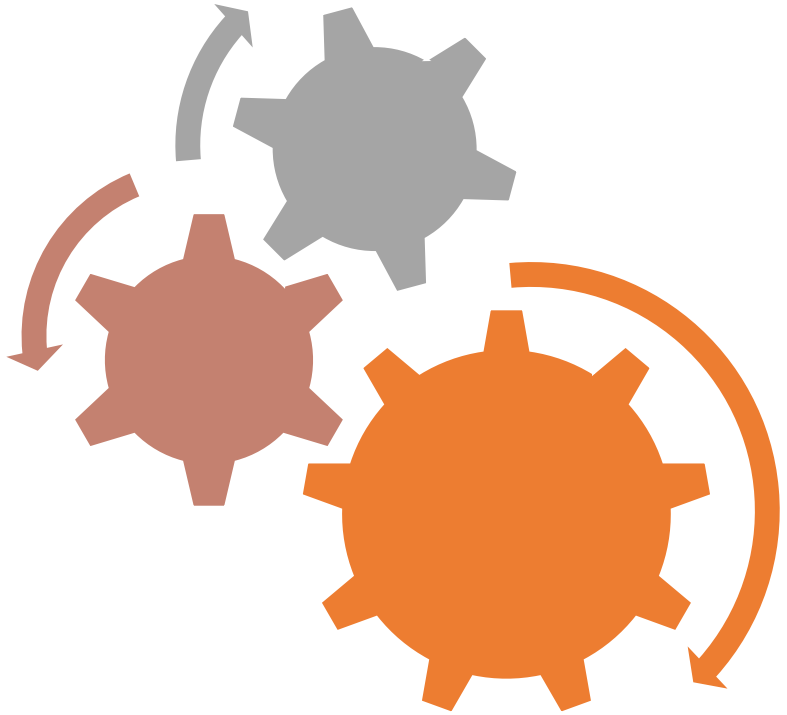
Key components of the module

Timeframe
- Delivered over a semester (3 hours per week contact time over 13 weeks)

Team-based
- Students are allocated to teams, each comprising 4-5 students

Resources
- Single academic to lead the module
- Scope for guest lecturers
- Classroom fitted with PC's
- TEC Algorithm booklet and worksheets, plus lecture material

Assessment
- 100% coursework via 2 assignments
- Peer assessment element



MIT Breakthrough technologies

"Technologies. People often ask, what exactly do you mean by "breakthrough"? It's a reasonable question—some of our picks haven't yet reached widespread use, while others may be on the cusp of becoming commercially available. What we're really looking for is a technology, or perhaps even a collection of technologies, that will have a profound effect on our lives"

https://www.technologyreview.com/lists/technologies/2018/

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MIT Breakthrough Technologies from 2018 (1-5)

1. **3-D Metal printing**: The technology can potentially create engineering parts that are not possible with conventional metal fabrication methods. Could this technology change the mass production of different products?
2. **Artificial embryos**: The technology builds on the potential of stem cells. Can the technology of synthetic human embryos be harnessed and what about the ethical dimensions?
3. **Sensing city**: Smart cities technology. Can the power of distributed sensing grids and big data be leveraged to enable development of new neighbourhoods?
4. **AI for everybody**: Cloud-based artificial intelligence (AI). Can machine learning tools be made available to a broader audience as well as new applications?
5. **Dueling neural networks**: Generative adversarial network (GAN) technology. Machines that are developing an independent ability to make sense of the world and what are the emerging applications for this technology?

https://www.technologyreview.com/lists/technologies/2018/

MIT Breakthrough Technologies from 2018 (6-10)

6. **Babel-fish earbuds**: Inspiration from the *Hitchhiker's Guide to the Galaxy*. Can the current clunky hardware be fixed to capitalise on mutually intelligible communication between languages in close to real time?
7. **Zero-carbon natural gas**: Clean energy technology. Can new carbon capture technology be successfully deployed to enable burning of natural gas while avoiding greenhouse gas emissions?
8. **Perfect online privacy**: Cryptographic technology. Can an emerging cryptographic technology called zero-knowledge proof be used to support improved online privacy and counter the risk of identity theft?
9. **Genetic fortune-telling**: DNA testing and related technologies. Can the data from large genetic studies and the resulting polygenic risk scores be utilised to help improve health outcomes?
10. **Materials' quantum leap**: Quantum computing technology. Can developments in quantum computing be harnessed to enable the modelling of highly complex systems across a range of potential applications?

https://www.technologyreview.com/lists/technologies/2018/

Module deliverables

1) **Formal Report** (assignment # 1) evaluating technologies suitable for commercialisation in accordance with the algorithmic approach that is used. The technologies evaluated should be selected from the MIT top 10 Breakthrough Technologies from 2018

2) **Business Plan** (assignment # 2) and strategic analysis of commercialisation of the technology identified in part 1 above

Main stages of the 'TEC Algorithm'

Part of the TEC module at LSBU

(1). Ideation and description

- This involves description of the technology and product idea(s)
- Initial development of the products and corresponding markets

(2). Assessment (Phases I and II)

- Functional assessment of the technology commercialisation opportunity (Phase I)
- Strategic assessment of the business opportunity (Phase II)

(3). Business plan

- Development of the business plan document to support the commercialisation of the selected technology
- Income and expenditure forecast

(4). Implementation of business plan

- Implementation of the business plan to enable the commercialisation of the technology
- Launch of start-up company

Stage 1: Ideation and description

- A series of worksheets are completed, which allow the technologies to be evaluated:
  - Technology description worksheet
  - Technology documentation
  - T-P-M (technology-product-market) worksheet
  - Summary of the product attributes
  - Initial market assessment (each market is segmented)

- Student teams undertake an initial high level evaluation of 10 technologies, followed by more detailed evaluation of 4 leading technologies

- Preferred technology (and product set) is selected – Stage 1 is detailed in assignment # 1

Stage 1: Ideation and description

Structure of the T-P-M worksheet

Technology

- Describe the technology
- Identify main features
- Maturity of technology

Product

- Product idea # 1
- Product idea # 2
- Product idea # 3
- Product idea # n

Market

- Market and user need # 1a
- Market and user need # 1b
- Market and user need # 2a
- Market and user need # 2b
- Market and user need # 3a
- Market and user need # 3b

Stage 1: Ideation and description (market segmentation)

Market	Segment	No. of potential sales	Price per unit (£)	Revenue (£)/segment
Market 1	Segment 1	125	£100	£12,500
Market 1	Segment 2	150	£100	£15,000
Market 1	Segment 3	175	£100	£17,500
			Total revenue for Market 1 =	£45,000

Segmentation

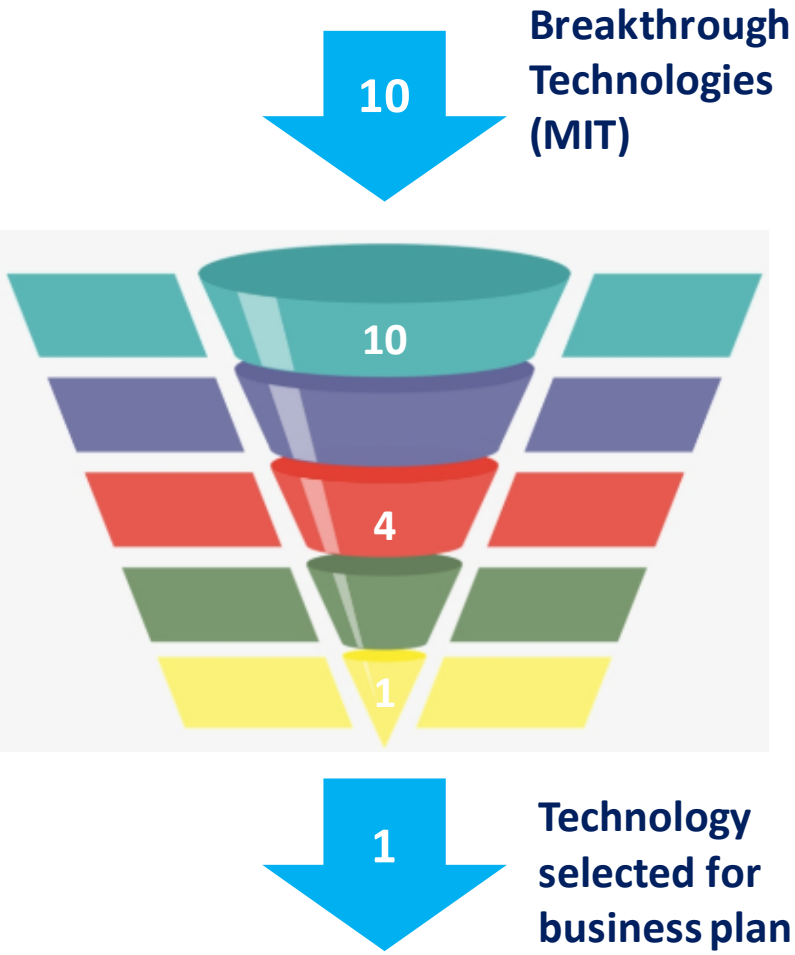
- Geographical segmentation
- Demographic segmentation
- Psychographic segmentation
- Behavioural segmentation

Marketing Mix (4 P's)

- Product
- Price
- Promotion
- Place

Stage 1: Selection of leading technology for commercialisation

- Evaluation of the 10 MIT Breakthrough Technologies in the initial ideation stage
- More detailed evaluation of 4 technologies, with assessment of the technology, product description and product attributes, market description and preliminary market assessment
- Other considerations:
  - How unique is the technology?
  - How extensive is the market for the technology?
  - What level of technology maturity (TRL – technology readiness level)?
  - Who are the potential competitors and suppliers?
  - What level of investment is required?



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Stage 2: Assessment

- This stage involves a further series of worksheets (as spreadsheets) to support the functional assessment of the technology commercialisation opportunity (Phase I) and strategic assessment of business opportunity (Phase II)

- The objective of Phase 1 is to eliminate product ideas (not technologies) based on commercial flaws. Data is entered into a number of assessment worksheets (in Excel). Assessment worksheets are categorised into the following 6 key areas:
  1) Legal
  2) Marketing
  3) Team-organisational
  4) Technology
  5) Operations
  6) Financial

- Each worksheet is based on the same assessment structure (**assessment is equivalent to a PESTLE analysis**)

PESTLE Analysis
- Political
- Economic
- Social
- Technological
- Legal
- Environmental

Stage 2: Assessment

- Strategic assessment (Phase II) involves more detailed assessment
- Responses are rated for magnitude and confidence as well as assigned a factor for SWOT
- There are five worksheets in the Excel file:
  1) Legal
  2) Marketing
  3) Organisational
  4) Technology
  5) Financial

SWOT Analysis

- Strengths (internal)
- Weaknesses (internal)
- Opportunities (external)
- Threats (external)

Stage 3: Business plan – inputs (1)

- There are several worksheets from the TEC Algorithm that support further analysis of the technology, product and market potential – this includes identification of the strategic factors from the earlier stages

- Identify strategic areas that are critical, e.g. product uniqueness, competitors, customers, etc.

- Identify the core assets of the proposed start-up:
  - Benefits of the technology for the customer
  - Mechanisms available to protect the core assets, e.g. through patents or registered design
  - Commercialisation pathways available (license arrangements, start-up company or joint venture)

- Chart the level of technical advantage against the ability to protect (2 x 2 matrix)

- Identify market entry plans as well as market development strategy

Stage 3: Business plan – inputs (2)

Further business analysis tools and models to be considered as part of business planning process

Porter's 5 forces

Allows competitive forces that shape an industry to be analysed

Value chain analysis (Porter)

Allows value adding functional areas of the business to be identified

Ansoff's matrix

Marketing planning tool that allows growth strategies to be identified – charting existing and new markets vs. existing and new products

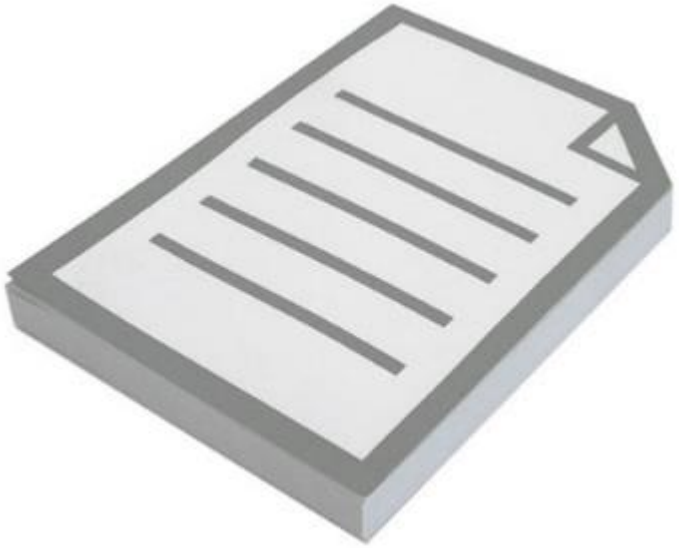
VRIO analysis

Business analysis framework to identify resources that assesses the value, rarity, imitability, and organisation of resources that provide competitive advantage

Stage 3: Business plan – document

- Business plan (assignment # 2) is assembled to support commercialisation of the selected technology

- Plan includes the following sections:
  - Executive summary
  - Problem and solution
  - Detailed description of the technology and product
  - Market analysis and marketing plan
  - Operational plan
  - Organisational structure
  - Financial analysis (including income and expenditure)
  - Risk register
  - Appendices

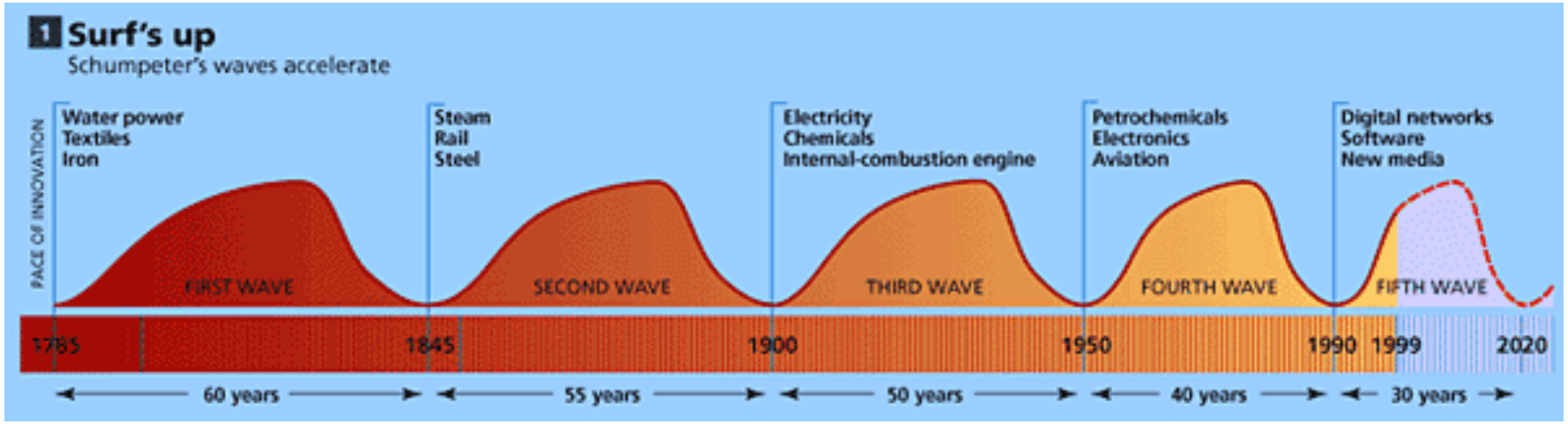


Weekly lectures for the TEC course

Week	Lecture title
1	Module introduction
2	Perspectives on R&D, technology management and innovation
3	Introduction to intellectual property (IP)
4	Developing a marketing strategy using the STP (segmentation, targeting, positioning) process
5	Insights from business planning for major research programmes and supporting infrastructure
6	Fundamentals of risk management
7	Exploring process-based innovation models
8	Guest lecture by industry representative
9	Introduction to financial analysis and return on investment
10	Business, innovation and commercialisation strategy frameworks
11	Summary and recap of lecture material
12	Finalisation of assignments
13	Submission of assignments

Example lecture slide: Creative Destruction and Joseph Schumpeter

- According to Schumpeter, the "*gale of creative destruction*" describes the "*process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one*"
- The economist Schumpeter linked innovation and technological change to the impact of entrepreneurs



https://www.economist.com/special-report/2014/08/11/catch-the-wave

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Schumpeter, J.A., 1942. *Capitalism, Socialism and Democracy*

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Example lecture slide: Managing technology with TRLs

- Technology readiness levels or TRLs – originally developed by NASA

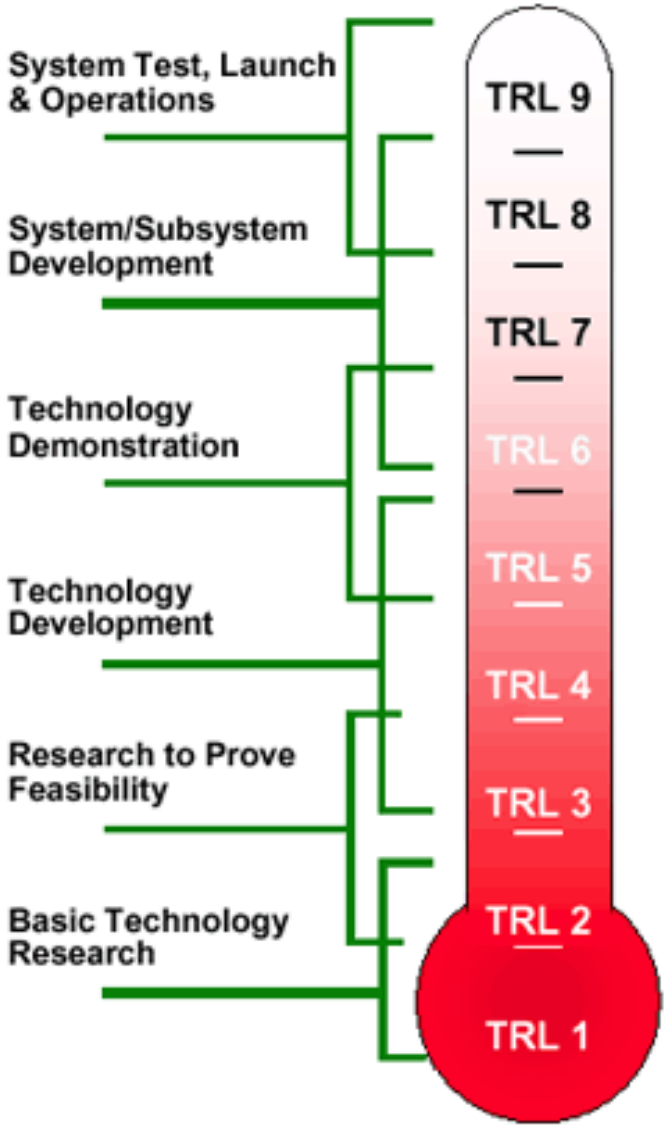
- TRLs are a method that allows the maturity of a technology to be estimated

Where do the following new technologies appear on this framework?

a) Self-driving cars

b) Stem cells

c) 3-d printing



https://en.wikipedia.org/wiki/Technology_readiness_level

https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

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Example lecture slide: Overall process for research commercialisation

Research and discovery	Identification of IP	Assessment of IP	Protection of IP	Exploitation of IP
Stage 1	***Stage 2***	***Stage 3***	***Stage 4***	***Stage 5***
The research project generates a new invention, relating to technology that has possible commercial value	The new technology is reported in an invention disclosure form. A commercial exploitation plan is developed	The new technology is assessed in context of the commercial market potential, plus competing technologies are assessed	If there is a clear and compelling commercial case, the patent application is filed in the required territories	In the case where the patent is granted, commercial exploitation can commence – either with start-up or other company

Example lecture contents: Introduction to financial analysis and return on investment

Subject	Details
Financial statements (x3)	• Income and expenditure statement, balance sheet, cash flow statement
Return on investment (ROI)	• Introduction and ROI calculation
ROI factors	• Timeframe, consistency, and precision
Cost analysis for ROI	• Start-up costs, expenses of tailoring innovative technology, and longer-term strategic outlays
Quantifying revenues for ROI	• Organisation, stakeholder, and technology adoption dimensions
Investment appraisal	• Calculation of net present value (NPV) – discounted cash flow technique, venture capital company investment example and exercise
Financial modelling	• Introduction, uses of financial models, types of models
Financial risks and financial ratios	• Definition and types of financial risk, financial ratios (categories and ratios provided)

(3). Insights and lessons learnt

Blending the TEC Algorithm with lecture material

- The TEC Algorithm contains many worksheets and it was found that not all of them were needed – especially in the latter part of the Algorithm – therefore flexibility was allowed

- Blending lecture material with the TEC Algorithm allowed broader knowledge to be made available across different aspects of technology commercialisation, e.g. related to IP (intellectual property) as well as a historical perspective on innovation models

- Lectures also allowed more detail to be covered in certain crucial areas related to the business plan, e.g. risk management and financial analysis

- Adopting this blended approach allowed the experiential learning to sit alongside the provision of complementary taught material

Team-based approach

- The assignments are delivered by students working in teams, but this has pros and cons…

Pros	Cons
• Students are faced with similar conditions to those faced by entrepreneurs setting up a real start-up company	• Not all team members contribute at the same level of input and with the same level of enthusiasm
• Students enhance their communication skills – both verbal and written	• Some team members may hide in the background
• Assignment workload can be shared across the team and according to the strengths of the team members	• There is the potential for conflict to arise between team members
• Students gain different perspectives from their peers	• Challenges in finding time to meet and discuss the work (especially part-time students)

Peer assessment

- The module included an element of peer assessment

- Important to set out at the beginning of the course the assessment criteria and how the process will operate:
  - Students rated each other anonymously
  - Rated their peers according to 4 questions (each from 1-6)
  - The questions related to the level of contribution of the peers

- Students engaged with the process – the benefit is that students are very close to the work and therefore have a clear understanding of the level of contributions of their peers

- Important for the module leader to have the ability to review the peer assessment marks and consider whether any changes are required

Lessons learnt

- There needs to be adequate time made available to assimilate all the detail from the TEC Algorithm and corresponding worksheets – if not, it may be overwhelming for some students

- Additional lecture material can help provide further background, context as well as additional tools and models, e.g. TRL framework, risk management (Ishikawa diagram), VRIO analysis, NPV (net present value) financial analysis, etc.

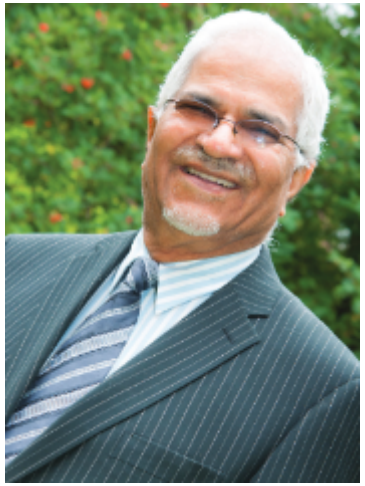
- Team-based projects can have pros and cons but on balance there is still merit in adopting this approach

- The experiential aspects of the module can be highly beneficial for the students – they are effectively participating in a start-up planning simulation – in terms of teaching practice this component requires more of a coaching approach

(4). Brief introduction to the Nathu Puri Institute for Engineering and Enterprise

History of the institute

- The Nathu Puri Institute (NPI) for Engineering and Enterprise at London South Bank University (LSBU) was launched in 2011 following a generous donation from the Puri Foundation
- NPI is part of the School of Engineering at LSBU
- The focus of the Institute is to embed enterprise into engineering education and industrial practice
- This is achieved through pursuing an integrated set of research, education and knowledge exchange activities



"Knowledge should be available to future engineers and engineering students so that more of them can break the glass ceiling and become entrepreneurs and our business leaders. Current demands are for engineers with a much wider knowledge base, hence this initiative today." *Professor Nathu Puri – Speaking at the launch event for the Institute*

Emeritus Professor Rao Bhamidimarri – Founder of the Institute

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http://www.lsbu.ac.uk/research/centres-groups/the-nathu-puri-institute

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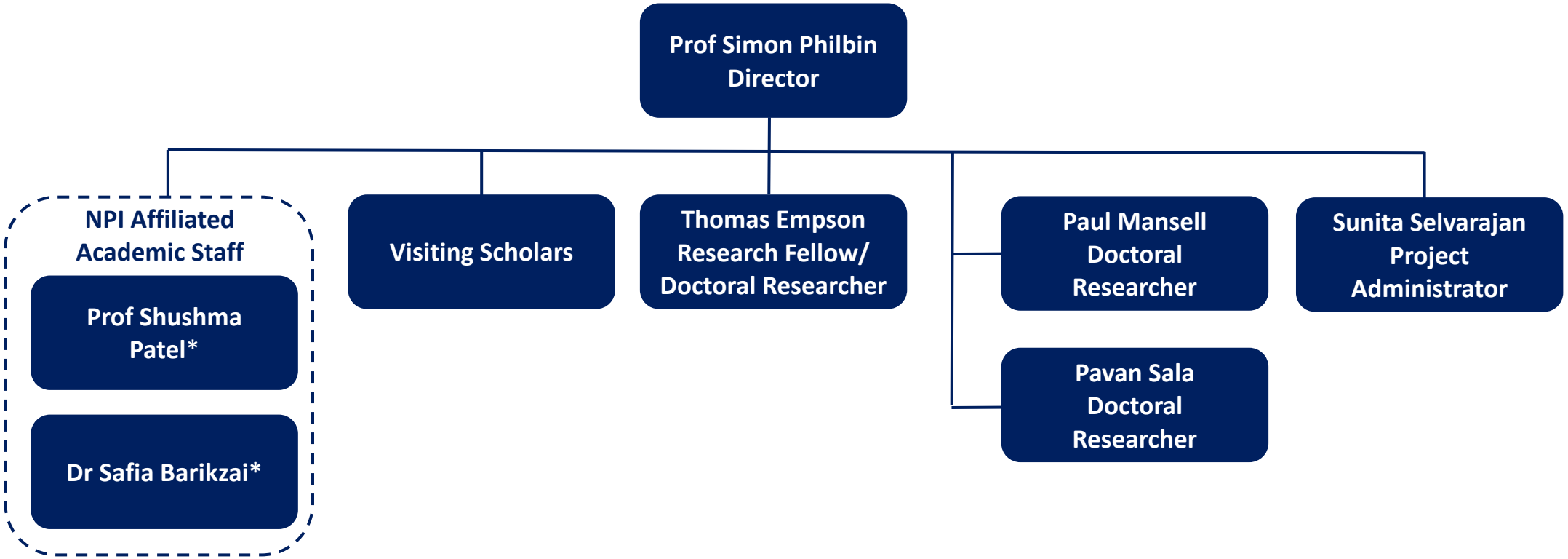
The NPI core team and affiliated staff



* Provides supervision/co-supervision of PhD students

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Institute research themes

1) **Enterprise for engineers** (includes understanding how enterprise, creativity and project management help engineers to be more effective and leverage their technical capabilities)

2) **Entrepreneurship for engineers** (includes understanding how engineers can be more entrepreneurial and more generally understanding tech entrepreneurship)

3) **Engineering education** (includes understanding how enterprise can be embedded more effectively as part of engineering education programmes)

4) **Technology development and innovation** (includes understanding how research and technology development as well as innovation impacts engineers and engineering organisations)

New online course developed with the IET

- NPI has developed the ‘Entrepreneurial Skills for Engineers’ online course in partnership with the Institution of Engineering and Technology (IET)
- Course team: Prof Simon Philbin, Thomas Empson, Robin Jones, Paul Mansell, Pavan Sala, Mausam Gaurav, Sunita Selvarajan
- The course provides the skills and knowledge that engineers can use as part of the entrepreneurial journey to develop innovative ideas through to new products and businesses
- The course launched in August 2019 as part of the IET Academy

Course units:

1) Introduction
2) Ideation and creativity
3) Leveraging research and development
4) Product design
5) Entrepreneurial finance
6) Capturing market needs
7) Managing innovation projects
8) Leading the team
9) Strategic business development
10) Driving continuous improvement into your business

The Institution of Engineering and Technology

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(5). Final remarks and acknowledgements

Final remarks

- Employers and industry are seeking for engineers to have professional and enterprise skills to complement the technical engineering knowledge – especially in the context of Industry 4.0 and other developments

- The Technology Evaluation and Commercialisation (TEC) module at LSBU integrates the process-driven TEC Algorithm with supporting lecture material – a blended experiential and taught programme

- Students are equipped with background knowledge on technology, innovation and business management as well as an understanding of the tools and techniques to support enterprise behaviours – and support those who are interested to become more entrepreneurial

- Within the NPI team at LSBU we are focusing on embedding enterprise skills into engineering education and industrial practice and the TEC module helps to achieve this goal

Acknowledgements

North Carolina State University (USA) is acknowledged for the original development of the Technology Evaluation and Commercialisation (TEC) algorithm

Dr. Goran Bezanov and James Barnham are acknowledged for the previous delivery of the TEC module at London South Bank University

Thank you for listening

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