Encouraging Technology Entrepreneurship for All

Simon Mosey

Abstract Drawing upon contemporary research, this paper observes a significant increase in the supply and demand for technology entrepreneurship education. Specific case examples are considered highlighting how engineers and scientists can learn technology entrepreneurship through creatively deploying research breakthroughs to address industrial and societal challenges. The relative merits of different methodological approaches to evaluate the impact of such educational approaches upon skills development and subsequent career destinations are discussed. Finally a case study is presented demonstrating how technology entrepreneurship can be supported on an unprecedented scale using novel online learning tools.

Keywords Technology · Entrepreneurship · Education · Online

1 Introduction

This paper highlights an increased need for technology entrepreneurship education defined as 'learning how to commercialise a new discovery to address an industrial or societal challenge.' Historically this type of activity was the preserve of the research and development divisions of large corporations (Royal Academy of Engineering 2012). However, consecutive waves of disruptive technologies have eroded the capability of such institutions to manage this process effectively. The breakthroughs in materials science, biotechnology, information technology and electronics have wrought disruption across industries in unpredictable and complex ways (Tidd and Bessant 2013). As a response to this change, the educational demand from engineers and scientists has shifted away from general technology

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management education such as that historically provided by corporate training and business school MBAs. This has been replaced by a demand for technology entrepreneurship education typically provided within incubator or accelerator environments (Feld 2012). Not only has the education environment changed but also the course content and pedagogical methods. Didactic and case based teaching has been augmented by entrepreneurial boot camps where lecturers are replace by inspirational speakers and historical case studies replaced by 'live cases.' Here engineers and scientists are encouraged to work in cross disciplinary teams with business, legal and finance experts in an iterative, experimental learning format combining fast failure with mentoring and expert guidance (Binks et al. 2006).

This paper reflects upon this shift and seeks to highlight case exemplars of good practice from across Europe. It then addresses a fundamental shortfall in the lack of systematic evidence of the efficacy of these contemporary teaching and learning practices. Evidence is presented of different evaluation methods including student feedback of changes in self efficacy and entrepreneurial intentions. Building from a critique of the rigour of such approaches, the relative merits of the different approaches to evaluate entrepreneurial skills development are considered. A longitudinal case evaluation is presented highlighting the potential longer term impacts of entrepreneurial boot camps upon the aspirations and destinations of participating scientists and engineers. The paper concludes with an introduction to one approach to scaling such pedogogy using online tools. Here the potential benefits of virtual teams and more effective use of scarce expert resources are posited.

2 From Technology Management Education to Technology Entrepreneurship Education

Clarysse et al. (2009) argue that the management and enterprise educational needs of engineers and scientists can be categorised by considering skills deficits and context of application. Using these categories they built a descriptive framework as shown in Fig. 1. Here they propose that the features by which educational offers vary can be positioned using two axes. First, they propose a skills provision axis ranging from general to specific skills. Second, they argue for an educational aims axis ranging from a focus upon individual career development to meeting an industry level need for more innovation and entrepreneurship. This builds a framework of four quadrants as shown below.

2.1 Technology Management Education for Career Development

The first, (bottom left) quadrant is where generic management skill development is integrated with a focus upon individual career development. This is traditionally

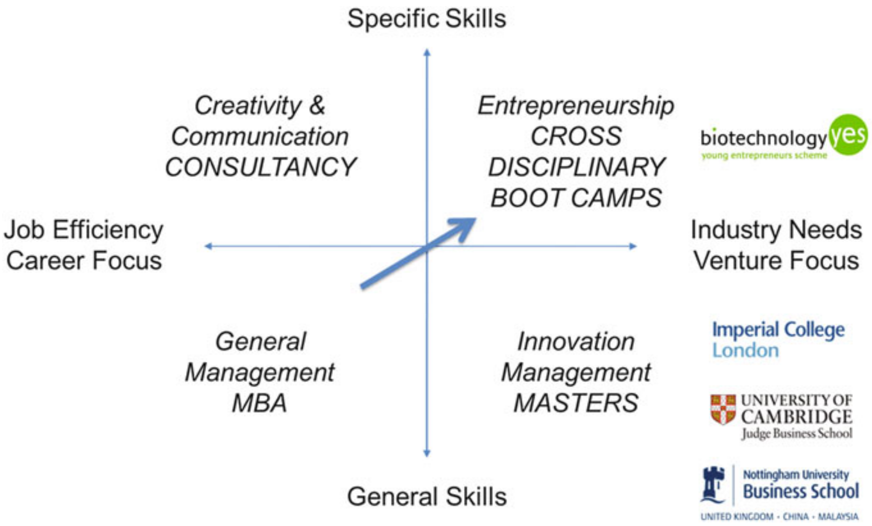

Fig. 1 Supply of management and enterprise education for engineers and scientists (Adapted from Clarysse et al. 2009)

where business schools offered open programmes such as MBAs. Such programmes have a long pedigree of helping engineers build their general management skills and thereby climb up the corporate career ladder. However such programmes are suffering from fierce competition due to the increase in providers and an awareness that general management training as provided by most business schools is becoming detached from the contemporary needs of corporate employers (Starkey et al. 2004).

By contrast, quadrant 2 (top left) integrates specific skills development, such as creativity training, with a similar aim of individual career development. Such programs are increasingly prevalent within blue chip organizations, to meet the need for more creative employees that can work more effectively across the organisation. Such an offer is rarely provided by Business Schools due to a capability gap in this area. Clarysse et al. (2009) observed organisations such as Rolls Royce and Alcatel employing consultants to provide such training.

2.2 *Technology Entrepreneurship Education for Industry Needs*

In the third (lower left) quadrant, we see the integration of generic skills together with industry specific aims. These are exemplified by the developments at the Cambridge MIT Institute. From 2000 to 2001 the Cambridge-MIT Institute aimed to transfer the cross disciplinary capability observed at MIT over to Cambridge to more effectively enact the practice of innovation. As a result, they redesigned some of the MPhil degrees at Cambridge to inculcate a more cross disciplinary approach to teaching and learning.

They built a suite of one year master's-level degrees aimed at scientists and engineers wishing to be more innovative. To cater for this emerging group, Cambridge offered new degrees in contemporary technology areas ranging from sustainable energy and nanotechnology through to biotechnology. These introduce students to the technological breakthroughs aiming to be absorbed by specific industry sectors and they all share a core management module in technology and innovation to better understand the commercialisation of that knowledge within existing organisations.

This lower left quadrant has seen a significant increase in providers with notable UK examples being the University of Nottingham creating MScs in Electrical and Electronic Engineering and Entrepreneurship, Sustainable Energy and Entrepreneurship and Computer Science and Entrepreneurship in 2005 and Imperial College Business School launching an MSc in Innovation and Entrepreneurship in 2012.

The final quadrant (top left) highlights the most novel area of specific skills provision to encourage greater levels of technology entrepreneurship. Binks et al. (2006) proposed that the most effective pedagogic models for developing such entrepreneurial skills was through integrative learning. Only through a combination of theoretical instruction from academics, practical coaching from industry experts and reflection upon entrepreneurial activity could such skills be effectively developed and delivered on a scalable basis. They considered how best to deliver such integrative learning for scientists and technologists. They concluded that entrepreneurial boot camps where participants enact the process of identifying, evaluating and presenting a commercialisation proposal for a novel technology to potential investors to be a highly effective educational method.

Within the UK this has been one of the fastest growing areas of training provision supported by research councils and corporate sponsors. For instance one of the longest running schemes is the Biotechnology Young Entrepreneurs Scheme (YES), an entrepreneurial boot camp for postgraduate life scientists, chemists and chemical engineers. The Haydn Green Institute for Innovation and Entrepreneurship (HGI) has worked closely with the Biotechnology and Biological Sciences Research Council (BBSRC) since 1995 to manage and deliver Biotechnology YES. A new growth plan was agreed in 2005 that introduced content and pedagogical additions based upon HGI research (see Wright et al. 2004; Mosey et al. 2006; Mosey and Wright 2007). This allowed for the scheme to grow and yet retain the rich learning experience enjoyed through small cohorts. The scheme pioneered the use of opportunity identification training, introduced peer reviewed investment pitches for all participants and provided interaction on a large scale with industrialists and equity financiers as mentors and judges across the whole cohort.

As a result, annual participation in the scheme grew from under 200 in 2005 to more than 400 in 2011. In total, more than 4500 academic researchers took part between 1998 and 2014. Expansion into other academic disciplines ensued with a variant for environmental scientists initiated in 2006 (with the Natural Environment Research Council) and two further schemes launched in 2009 to bring this unique delivery model to the engineering and sustainability research communities (with the Engineering and Physical Sciences Research Council).

This growth was further accelerated through wider (industry) partnerships: a bespoke competition was held for microbial and plant scientists at Syngenta's Jealotts Hill research site in 2011. Here participants were tasked with addressing bespoke industry specific challenges using breakthrough technologies. Similarly, a competition for biomedical scientists was launched at GlaxoSmithKline's Bio incubator in Stevenage in 2012, together with the Medical Research Council and Welcome Trust. The CEO of the Bio incubator explained the added value of hosting the competition on industrial sites:

> I've seen many times the value and benefit young entrepreneurs can derive from being exposed to an incubator and seeing for themselves what can be achieved away from academic research. It is a highly networked atmosphere they are not traditionally exposed to early in their careers – a space where early start-ups develop and grow. It's a whole new world which provides a real-life focus.
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> Martino Picardo, CEO of GSK Bio Incubator, 2012[1]

This continued expansion has been highly endorsed by the UK Government:

> I would like to congratulate all the participants of the Biotechnology and Environment YES competitions on their success. Scientists who are able to combine their expertise with an understanding of business are a very precious resource. By learning how to translate research into wider successes, they can help ensure their work delivers the maximum benefits to society and the economy. I am impressed that the participants are taking the opportunity to develop their skills and knowledge at this early stage of their careers - it suggests a bright future for the commercialisation of UK research.
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> David Willetts, Minister for Universities and Science, 2011[2]

In terms of supply and demand the trend in the UK seems to be towards industry and venture focussed skills development, with a particular emphasis upon technology entrepreneurship. The demand side appears driven by the disruptive nature of technology developments in ICT, biotechnology and cleantech that can not be easily absorbed within current industry business paradigms (Royal Academy of Engineering 2012). However regarding the supply side there is a relative lack of evidence of the impact of these contemporary forms of technology entrepreneurship education.

[1]http://www.bbsrc.ac.uk/news/people-skills-training/2013/130502-f-enter-now-for-biotechnology-yes/.

[2]http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=28495.

3 Evaluating the Impact of Technology Entrepreneurship Education

There is an emerging body of evidence for the impact of the upper left quadrant type technology entrepreneurship education, the entrepreneurial boot camp. The most frequently cited form of evidence is student feedback and there is a healthy debate regarding the validity of such an approach. In summary, numerous constructs have been tested and validated to capture students views of their self efficacy and entrepreneurial intentions before and after taking boot camp type courses (Souitaris et al. 2007). However the relationship between self efficacy, intentions and entrepreneurial action is complex and context specific (Mosey et al. 2007). Moreover, some authors argue that a decrease in self efficacy and entreprenurial intentions of students following a boot camp experience is a positive validation of the impact of the course as it has therefore given students a more realistic appreciation of the challenges inherent in the practice of entrepreneurship.

3.1 Evaluating Entrepreneurial Skills Development

DeTienne and Chandler (2004) take a different approach. They argue that capturing an increase in students capability to identify new business opportunities is a more reliable measure of the impact of technology entrepreneurship education. They developed before and after tests where students are asked to identify new business ideas within a short time period. Experts subsequently categorised both the number of innovative ideas and the quality of those ideas and in this way any increase in capability as a result of the course can be isolated.

Munoz et al. (2011) built upon this approach by also asking students to pictorially represent their understanding of the process of entrepreneurship before and after taking the course. Building upon the work of Zuboff (1988) and Clarkson (2008) these visual representations were analysed for evidence that the students had enhanced their understanding of how entrepreneurship works in practice. There was a remarkably correlation between those students that increased their capabilities to identify new business opportunities through taking the course and those who showed a significant change in their visual representation of entrepreneurship. Figures 2 and 3 below show visualisations drawn by Christopher, a students who did not develop his entrepreneurial capabilities during the course. Here it is clear that there is also a corresponding lack of change in his representation of the practice of entrepreneurship.

By contrast, Figs. 4 and 5 show the visualisations of Michael, a student who significantly increased his capability of identifying new business opportunities through taking the course. Here we can see a corresponding change in his understanding of the practice of entrepreneurship through the changes in drawings.

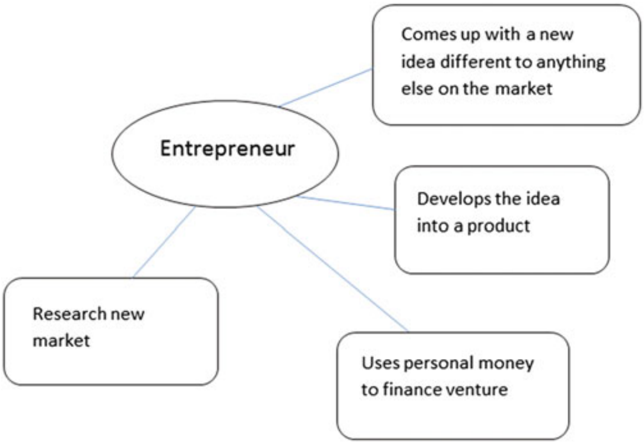
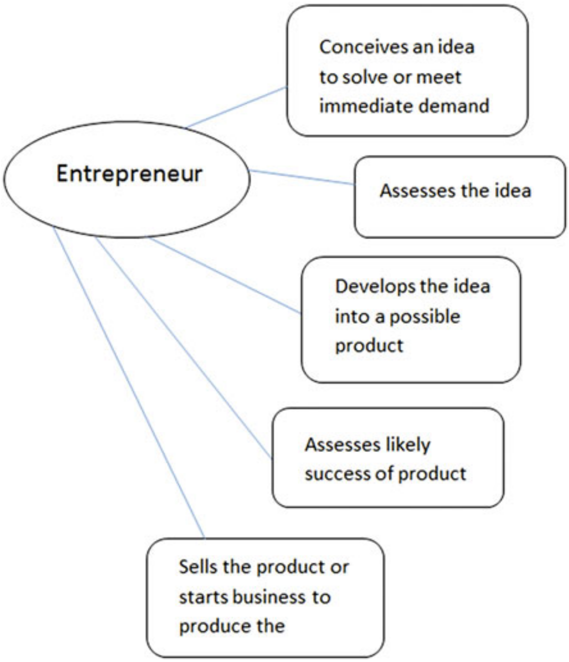


Fig. 2 Christopher, first interview. Student who did not develop his entrepreneurial capabilities during the course

Fig. 3 Christopher, second interview. Student who did not develop his entrepreneurial capabilities during the course



However it still remains to be seen whether this increase in capability and understanding translates into entrepreneurial activity. In the following section we consider the Biotechnology YES scheme which has been established for a twenty year time period over which such outcomes can be realistically evaluated.

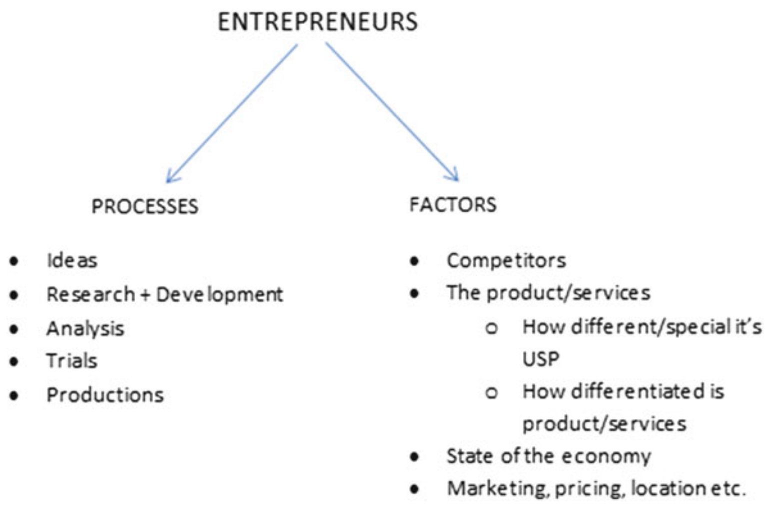


Fig. 4 Michael, first interview. Student who developed his entrepreneurial capabilities during the course

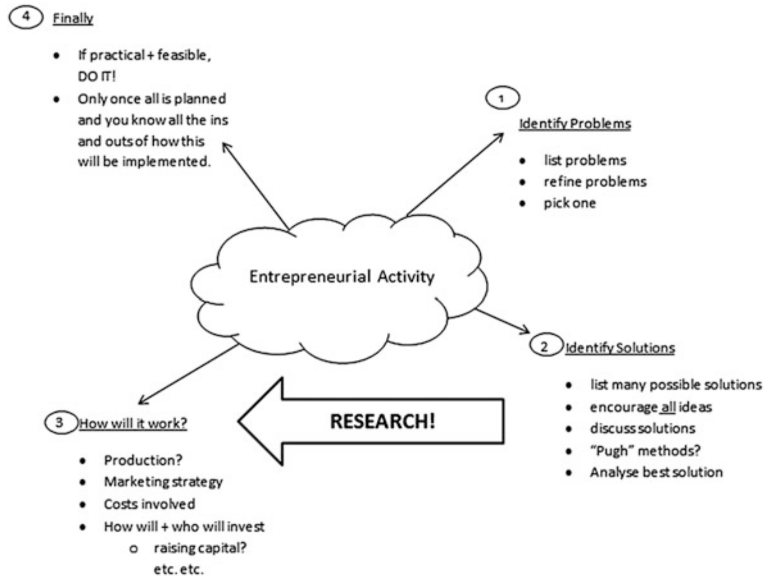


Fig. 5 Michael, second interview. Student who developed his entrepreneurial capabilities during the course

3.2 *Evaluating Skills Development and Subsequent Careers Destinations*

Webb (2010) conducted an independent review of the Biotechnology YES scheme, commissioned by the BBSRC. They reported that:

Biotechnology YES participants were found to develop a different set of skills than those developed through taking a Ph.D. Specifically commercialisation knowledge, financial awareness and the ability to communicate in a commercial setting were all increased as illustrated in Fig. 6.

Reinforcing the work of Munoz et al. (2011), the participant feedback on completion of the programme presented a common consensus regarding their view of skills developed as a result of participation. They stated that they developed skills in financial awareness, team working, management, verbal communication, and time management within a commercial context. For example:

> I thought the YES experience was excellent. Perhaps my opinion of the course is slightly biased because our team performed well in the competition, but I have taken many varied skills away from the course. The commercial aspect of science is still one that is poorly understood within my faculty and this course gives a great insight into the business world for an emerging scientist/manager/entrepreneur.
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> Participant, 2009 (see Footnote 2)

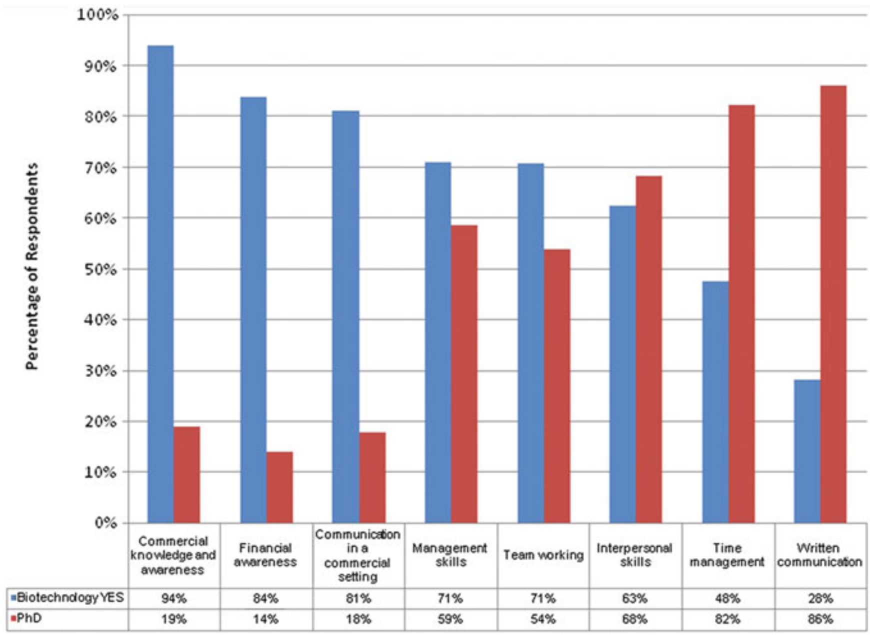

Fig. 6 Reported skills development of participating in Biotechnology YES versus those gained from studying for a Ph.D. (Adapted from Webb 2010)

In terms of the longer term impact, Biotechnology YES was found to have a significant impact upon the career aspirations of participants by developing a greater awareness of employment opportunities outside academia and enhancing the propensity to set up their own business. A higher proportion of participants were employed within industry than those researchers that did not participate and Biotechnology YES had a consistent fit with UK and international entrepreneurship and innovation policy.

The evaluation also found that former participants highlighted substantial career and business impacts attributed partly to YES. These ranged from:

> salary uplifts of up to 25 % and 5-60 % of business success being attributed to YES. The financial benefits ranged from £5 k p.a. of self-employed turnover to £200 k of investment funding and, from one business alone, potential licensing income of £3 M. [Webb 2010, page 62]

Despite this strong evidence of impact, there still remains a significant constraint upon the widespread delivery of such programmes. Clarysse et al. (2009) argued this to be a shortage of human capital, a lack of academics and industrialists that have the experience, capability and credibility to deliver such programmes. Mosey et al. (2006) qualified this more specifically as a shortfall in individuals that have the experience to span the different networks of academe and industry.

However, a new development at the University of Nottingham could help address this limitation. Academics at the Haydn Green Institute working together with an entrepreneurial education software provider have developed an online version of the entrepreneurial boot camp experience. This has been successfully deployed with undergraduate students working in virtual teams across the university. The outcomes are summarised in the case study below and although at an early stage this system offers a possible solution to a significant constraint to offering technology entrepreneurship to all.

3.3 Case Study of Using Online Learning for a Cross Campus Entrepreneurial Boot Camp

The Undergraduate Ingenuity Prize is an annual entrepreneurship competition open to students at The University of Nottingham. Participants attend a training boot camp which aims to help them prepare an entry for the competition by taking them through the Ingenuity Process to identify a societal or industrial problem and potentially discover a technological solution. The result of this process may form the basis of their business plan for submission as an entry into the competition. 2015 was the first time that Ingenuity Online, an online version of the teaching and learning approach, had been used at the boot camp for participants.

98 students took part from 28 schools across the University. Roughly half of the students had a business idea that they were bringing to the boot camp versus half without an existing idea. The role of the Ingenuity Process was to help those

students without a business idea to identify an opportunity to develop one and to help those with existing ideas to break them down and ascertain whether there is a demand for their product or service and if their idea is the best possible/most innovative solution to their identified problem.

During the boot camp, the teams were led through the three stages of the Ingenuity Process (Kirkham et al. 2009) using Ingenuity Online. Team members used laptops and mobile devices to access the software and set up their own challenge to work through. Each team was also allocated an external business mentor who accessed their teams' challenges and gave guidance during the process. The mentors gave a mixture of face-to-face support and also took the time to step away from their teams and mentor them solely via the software.

3.4 The Impact of Using Ingenuity Online Learning Tools

The software was seen to encourage users to input a large volume of ideas which are sorted into categories before one is chosen to develop as a solution to the identified problem. In this case, the solution that will be developed forms the student's business plan. The nature of using an online platform to capture ideas is that the students input their ideas by typing them in, rather than having to voice them to the group. This seemed to encourage more ideas to be solicited as there was less pressure on team members to explain or justify an idea. The idea is typed in and participants quickly move on to the next thought. Groups contributing collaboratively in this manner also removed the need for a team spokesperson. This in turn allowed less vocal team members to input just as many ideas as those who are more outgoing.

The boot camp teams were encouraged to come up with more and more ideas against the number generated by their peers. The element of competition within the room encouraged participants to throw more ideas into the mix which gave them a richer pool of possibilities from which to glean a solution. The students were able to re-visit their ideas saved in their challenge within the software and receive additional input from mentors before they submitted their entry to the competition. This had not been possible in previous years when support was limited solely to the boot camp session.

Following the boot camp event, 28 teams submitted a business plan to the competition. Compared to previous years these entries were more cross disciplinary, cross cultural and global in outlook. For example they included overseas projects creating sustainable micro economies in Malawi as well as building recreation spaces in India's overpopulated cities. We also observed highly innovative products that aim to improve sports therapy treatments through to a novel patentable paint packaging product.

4 Conclusion

This paper presents a broad view of the increasing supply and demand for technology entrepreneurship training for engineers and scientists. By considering different evaluation methods it demonstrates that entrepreneurial boot camp pedagogical techniques where students work on commercialising novel technologies together with expert mentors can be highly effective in terms of skills development and encouraging entrepreneurial careers destinations. It highlights a human capital constraint in terms of expanding these programmes and concludes that online learning tools offer potentially novel extensions to the method that require further consideration and experimentation.

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