



Developing entrepreneurial competences in biotechnology early career researchers to support long-term entrepreneurial career outcomes

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ABSTRACT

This paper explores how early career biotechnology researchers develop entrepreneurial competences through participation in a bespoke entrepreneurship education competition and whether this affects their longer-term entrepreneurial actions. Specifically, we discuss the pedagogy and evaluate the short- and long-term impact of a long-running entrepreneurship competition, where biotechnology doctoral and postdoctoral researchers address societal and environmental challenges through hypothetical new venture creation. We present evidence regarding the efficacy of this experiential education, where online mentoring is blended with a team-based residential competition utilising inspirational speakers, practitioner support and peer learning in encouraging ECRs to consider commercialising their research. We conclude that long-term entrepreneurial career outcomes can be fostered through tailored short-term interventions.

1. Introduction

Entrepreneurial activity within academia has become an international priority (Wright, 2014; De Silva, 2016) due to the positive impact upon knowledge-based regional development achieved through the commercialisation of research results and the provision of highly-educated, entrepreneurial graduates into regional labour markets (Bienkowska and Klofsten, 2012). Hence, the demand for universities to facilitate knowledge exchange is increasing, from both policy and funding channels (Thune, 2009; Dooley and Kenny, 2015), driving academic entrepreneurship and closer university-industry ties (Muscio and Ramaciotti, 2019). European Union policies have, in recent decades, promoted entrepreneurship education within universities (Brentnall et al., 2018), to foster entrepreneurial attitudes and competencies amongst faculty and students (Bienkowska et al., 2016); with an increasing emphasis upon post-graduate researchers (Thune, 2010; Dooley and Kenny, 2015). To realise the potential contribution to economic growth (Blenker et al., 2008) and regional development (Bienkowska and Klofsten, 2012), targeting entrepreneurship education at post-graduate researchers is apposite given that they undertake the majority of research in Universities (Enders, 2002; Bienkowska and

Klofsten, 2012) and could be undertaking innovative research with commercialisation potential (Thune, 2009, 2010; Dooley and Kenny, 2015).

This entrepreneurial university context requires additional competencies from post-graduate researchers in order to navigate academy-industry demands, commercialise research and establish successful academic careers (Thune, 2009, 2010). However, given that doctoral students and post-doctoral researchers are unlikely to attain tenured academic positions, they must nurture the intrapreneurial skillset required by employers in the labour market (Phillips, 2010). An entrepreneurial mindset and competencies are, therefore, required by both doctoral and post-doctoral researchers for their future careers, whether in academia, as an entrepreneur or within industry (Hayter and Parker, 2019).

It is accepted that entrepreneurship education for post-graduate researchers, particularly in SET (Science, Engineering and Technology) disciplines, needs to incorporate knowledge and awareness of the commercialisation process (Rasmussen, 2005; Phillips, 2010). Dooley and Kenny (2015) found entrepreneurial skills developed during post-graduate research can influence future entrepreneurial capabilities; while Muscio and Ramaciotti (2019: 21) established that

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provision of entrepreneurship education is positively and significantly associated to the probability of establishing a firm. Dooley and Kenny (2015) also established that over eighty-seven percent of post-graduate researchers appreciated the value in taking entrepreneurship education offerings outside their discipline-specific research programme, but seventy-percent reported insufficient educational offerings available to promote effective commercialisation activity. The post-graduate researchers expressed a preference for entrepreneurship education, rather than generic business or management offerings, delivered in a three-day block format (Dooley and Kenny, 2015: 100). However, effective entrepreneurship interventions remain a 'black box' with Nabi et al. (2017) calling for pedagogy and delivery mechanisms to be unpacked and explored.

Herein, we outline an effective entrepreneurship education intervention, targeted at doctoral and postdoctoral students undertaking innovative research (Thune, 2009, 2010), that fosters the requisite "entrepreneurial values...needed for commercialization" (Thune, 2010: 465). Moreover, via a longitudinal evaluation and follow-up, we contribute to knowledge and understanding of the potential for short-term entrepreneurship interventions to influence long-term entrepreneurial and commercialisation outcomes.

While we acknowledge that the population of doctoral-students and doctoral holders is not homogeneous (Bienkowska et al., 2016), they share many similarities in that they both have advanced subject knowledge and work in disciplines with scope for innovation, they may be working on research with commercial potential, are at the point of making career-shaping decisions, are likely to face uncertain employment futures and both require similar support and training should they wish to pursue entrepreneurial careers. These similarities support the meaningful evaluation of enterprise-education related outcomes targeted at both groups (Phillips, 2010). Following the UK Research and Innovation Economic and Social Research Council definition¹ (ESRC-UKRI, 2019) we categorise these, post-graduate research students and post-doctoral researchers collectively, as Early Career Researchers (ECRs).

SET ECRs attract significant UK government funding via Research Councils, doctoral programmes, scholarships etc. The contemporary review of UK higher education funding justifies this Government investment in such high-cost, resource-intensive disciplines (Augur, 2019), to develop highly-skilled SET researchers and support their research, given its potential to create economic value (Bienkowska et al., 2016). Yet, despite decades of targeted national and international policy initiatives to promote commercialisation from doctoral research in SET disciplines there remains a shortfall in SET entrepreneurial activity (Audretsch et al., 2015).

Thus, UK Government policy, influenced by key reports (Harris, 1996; Roberts, 2002; Lambert, 2003), has promoted entrepreneurship education within SET disciplines to encourage wider-scale commercialisation and maximise return on their investment. This is based on the premise that SET ECRs lack the requisite skills and knowledge to engage effectively in entrepreneurial activity due to a lack of related curriculum content (Henry and Treanor, 2012). Research suggests that entrepreneurship education interventions are more effective if tailored to provide bespoke knowledge, reflecting the characteristics and challenges of particular sectors, such as that of SET disciplines (Maresch et al., 2016). However, the skills shortage in relation to SET entrepreneurship is still considered a key economic problem in the UK (NAO, 2018), as crowded scientific curricula still tend not to incorporate entrepreneurship education as a core component.

Consequently, we argue, there is a need to identify how universities can effectively assist the requisite skills development to

promote entrepreneurial activity within SET ECRs to assist long-term knowledge transfer activities. To aid replication of good practice, it is also important that pedagogical approaches and teaching and learning activities are analysed (Nabi et al., 2017). Given that the exclusion of entrepreneurship education within SET programmes of study is considered a significant constraining factor in the development of entrepreneurial competencies or aspirations within the ECR community (Wright, 2014; Moog et al., 2015), we explore an entrepreneurship education programme - 'YES' - that has been delivered nationally in the UK since 1995. We focus on the Biotechnology stream participants as this is the longest running strand of the competition and a specific area of SET within the UK that has received sustained support from the investment community (UK Biotech Database, 2017). Within this unique data set we seek to explore:

- 1 *How can entrepreneurship education interventions support entrepreneurial competency development among biotechnology ECRs?*
- 2 *Can the development of such short-term individual outcomes promote long-term entrepreneurial and/or knowledge transfer activities?*

Within this paper, we offer theoretical and practical contributions in relation to entrepreneurship education. First, we contribute to pedagogy and practice by outlining the pedagogical approach and delivery considerations that facilitate entrepreneurial competency development as part of the YES programme. We show how the pedagogy of the scheme addresses specific and measurable entrepreneurial competency gaps for SET ECRs (Rasmussen and Wright, 2015) in particular. A key issue in the entrepreneurship education literature is whether entrepreneurship education can foster long-term entrepreneurial activity outcomes, given that research has tended to be cross-sectional and considers only short-term entrepreneurial intention development (Thune, 2010; Muscio and Ramaciotti, 2019). In response to calls for research to evaluate the longer-term impact of entrepreneurship education upon entrepreneurial competencies and activity (Pittaway and Cope, 2007; Nabi et al., 2017), we make a key contribution by demonstrating that even short-term entrepreneurship education interventions can facilitate long-term outcomes and impacts. Due to the longevity of YES, we can evaluate impact over the longer-term which acknowledges the longer time-lag in the SET research and commercialisation environment (Rasmussen et al., 2011) that has challenged evaluation in this context. Given the omission of entrepreneurship education from crowded scientific curricula which contributes to the ongoing skills-deficit among SET graduates and deficit in commercialisation activity, establishing the ability of a short-term, extra-curricular intervention to foster entrepreneurial competencies is apposite. Establishing the ability of such short-term interventions to contribute to entrepreneurial or commercialisation outcomes over the longer-term is crucial. This research has implications therefore, for policy makers, entrepreneurship education practitioners and evaluators.

To achieve our research objectives, the paper commences by critically evaluating the relevant literature pertaining to entrepreneurship education and evaluation before considering the pedagogy and delivery of the YES programme. We then outline our approach to evaluation prior to reporting our findings followed by a discussion of how the requisite competences for long-term entrepreneurial and commercialisation activity can be supported by short-term, competition-based, blended entrepreneurship education interventions. Having highlighted the limitations of our research and future research avenues, we conclude by considering the novel pedagogical aspects of the YES programme and call on Higher education institutions and SET faculty to support SET ECRs in acquiring these competences to support entrepreneurial career aspirations.

¹ The ESRC-UKRI definition identifies "three distinct stages for an early career research 1) Doctoral 2) Immediately Postdoctoral 3) Transition to Independent Researcher" (ESRC-UKRI, 2019).

2. Literature analysis

2.1. From policy to good practice in entrepreneurship education

European policy promotes the inclusion of entrepreneurship education (EE) within higher education curricula across disciplines as a means of supporting new venture creation and commercialisation to boost productivity and economic performance (Henry and Treanor, 2012; Lackeus, 2015). Despite the benefits of exposing SET students to entrepreneurship education being repeatedly articulated within the business and management academy (Hynes and Richardson, 2007; Fayolle and Gailly, 2015; Turner and Gianiodis, 2018) and being a maintained UK government policy focus (Dearing, 1997; Davies, 2002; Lambert, 2003; National Science Learning Centre, 2008; Science and Learning Expert Group, 2010; BEIS, 2017) it often remains peripheral to undergraduate programmes and is usually absent in post-graduate research programmes (Lackeus, 2015).

Pedagogy has been a key focus of research (Pittaway and Cope, 2007; Neck and Corbett, 2018) with consensus that entrepreneurship can be taught and learned through competency development (Gibb, 2005; Kuratko, 2005; Fayolle and Gailly, 2015). Action-oriented, experiential learning that is problem-solving, project-based and involves creativity is recommended (Gilbert, 2012; Lackeus, 2015) as practical, 'learning by doing' approaches are more student-learner centred, with problem-solving enhancing student engagement and the likelihood of deep learning (Tang and Ng, 2006); thus, producing more enterprising, innovative and self-reliant students (Hartshorn and Hannon, 2005: 618; Lackeus, 2015). This is underpinned by utilising teaching and learning activities such as those identified as 'best practice' by the World Education Foundation (WEF, 2009); these include:

- practical case studies, especially of high growth enterprises (written, live or video);
- group and team techniques for creating new business ideas and managing growth;
- business games and simulations (for business formation, early development and growth of the enterprise);
- lectures from entrepreneurs and other practitioners (possibly in connection with visits to high-growth enterprises);
- interviews with entrepreneurs, especially high-growth entrepreneurs;
- project work;
- development and assessment of business plans; and
- foundation of student enterprises (development of new venture creation and growth projects) (Henry and Treanor, 2010: 615-616).

These 'learn by doing' approaches are considered good practice and are proven to engender entrepreneurial competence development (Neck and Greene, 2011; Lackeus, 2015). For this reason, business-plan-based competitions have also been promoted by European policy as good practice vehicles of entrepreneurship education, with the competitive element considered to foster greater engagement (Brentnall et al., 2018). However, the adoption of new technologies to facilitate learning is now strongly advocated with blended-learning approaches, the use of both technology and classroom delivery, considered to enhance learning benefits for students (Fry et al., 2008).

2.2. Entrepreneurial competences

Entrepreneurial competences are considered to be a combination of knowledge, skills and attitudes that can be learned, changed and acquired through experience, training or coaching (Man et al., 2002; Volery et al., 2015; Kyndt and Baert, 2015) supporting venture birth, survival and/or growth. Research has sought to establish the entrepreneurial competences required for successful research-based

venture creation (Rasmussen et al., 2011), recognising that those competences necessary to create such a business, differ from those required to manage it through growth (Man et al., 2002; Mitchelmore and Rowley, 2013; Kyndt and Baert, 2015).

Necessary skills for successful entrepreneurship have been identified and include oral presentation skills, interpersonal skills and the ability to prepare and present a business plan (Bird et al., 2012). Socio-technical skills pertaining to communication, social skills and social networks have also been established as important in the SET context (Lamine et al., 2014; Lamine, 2017). In the academic context, requisite entrepreneurial competences relate to motivated individuals, the ability to discover and develop opportunities and to acquire resources to exploit those opportunities (Rasmussen et al., 2011). However, academics, particularly ECRs usually lack entrepreneurial competences (Sanchez, 2013; Siegel and Wright, 2015) due to a lack of business experience and commercial skills (Rasmussen and Wright, 2015). A recent study by Munoz et al (2019) highlighted these limitations within the academic SET environment in Chile and showed how entrepreneurship education could provide valuable entrepreneurial competences for early career researchers. They found that appropriate education could provide entrepreneurial competences that positively influenced entrepreneurial intentions but concluded with a call for more research examining the longer term impact of such interventions.

2.3. Evaluating EE effectiveness

Evaluations of EE typically assess effectiveness through establishing the development of short-term outcomes such as entrepreneurial intention or entrepreneurial competence development (Bird et al., 2012; Rasmussen et al., 2011). The EE interventions evaluated are usually longer-term, elective entrepreneurship programmes – delivered over at least six months (Peterman and Kennedy 2003; Souitaris et al., 2007). Zhao et al. (2005) highlight the gap in the literature surrounding short-term interventions and different formats of educational offerings available. They assert the need to "fully evaluate the effectiveness of different types of entrepreneurship programs depending on their key components (content, design, and delivery)" (Fayolle and Gailly, 2015: 76). The most common short-term intervention delivery format is the business plan competition, which the European Commission has benchmarked as a good-practice entrepreneurship education vehicle for some time (EC 2006; EC 2012; EC2013; EC2015); although, the evidence base for this is unclear (Brentnall et al., 2018).

Fayolle and Gailly (2015) analysed the impact of a short, compulsory, entrepreneurship education programme, delivered over a three-day period. They established that such a short-term intervention could foster entrepreneurial competences but highlighted that, regardless of programme duration, understanding of the longevity of these effects remains opaque (Fayolle and Gailly, 2015). Thus, potentially due to the lack of longitudinal data and cohort tracking, it has not yet been meaningfully established if entrepreneurship education, which fosters short-term individual competences or intentions, leads to long-term impact and related outcomes such as entrepreneurial activity or commercialisation. Indeed, the key critique of research evaluating entrepreneurship education effectiveness is its tendency to focus on short-term subjective impact measures rather than longer-term, outcome-oriented measures such as venture-creation (Nabi et al., 2017: 278). In recognition of this research gap, this paper considers an elective, short-term, tailored, experiential entrepreneurship education intervention, culminating in a business plan-type competition, to establish long-term impact in terms of commercialisation and new venture creation activity. We then explore if respondents consider their longer-term outcomes are related to the short-term subjective impacts derived from YES programme participation.

3.0. YES programme pedagogy and delivery

YES is a national entrepreneurship education intervention, culminating in a competition format, that has been delivered annually across the UK since 1995. Delivered by a UK university recognised by the Times Higher as a winner of Entrepreneurship University of the Year in 2008, it has been designed to compensate for the lack of university support programmes to encourage and develop entrepreneurial competences amongst SET ECRs in the UK. The programme specifically targets SET subjects with tracks relating to biotechnology, energy, engineering, environment and the digital economy (see www.yescompetitions.co.uk). The intention of the programme is to explain and explore the commercialisation process by offering dedicated support to enable participants to experience how breakthrough research can be shaped into a potential new venture. The programme has an organising committee with representatives from the Biological and Biosciences Research Council (BBSRC), the Natural Environment Research Council (NERC), and the Medical Research Council (MRC), UK government agencies responsible for the allocation of research funding and researcher professional development. The delivery team comprises of administrators, academic staff and over 300 speakers, mentors and judges drawn from sponsor organisations including large corporates, equity providers and numerous academic entrepreneurs.

Following Nabi et al.'s (2017) call for more explicit discussion of pedagogy within studies discussing the impact of entrepreneurship education offerings, this section provides an overview of the pedagogy underpinning the YES programme. The pedagogy is unusual in that it is a national competition format in which the challenge is for self-selecting teams of ECRs to prepare plans for a hypothetical start-up company seeking equity investment. The aims and learning objectives for the YES programme have remained consistent over time. ECRs, by the end of their participation in the competition will:

- Understand the process of commercialising research ideas
- Be able to communicate research with impact
- Enhance transferable skills in relation to: problem-solving, team working and communication.
- Develop and demonstrate the entrepreneurial competences of: Opportunity development, championing and resource acquisition.

YES is designed to maximise 'constructive alignment' (Biggs, 2003); the learning objectives, teaching and learning activities and assessment are aligned to facilitate student-centred learning so participants can achieve learning outcomes. Thus, a combination of activities and approaches are used to ensure participant engagement and experiential learning (Kolb, 1984).

Prior to engaging with competition workshops, an online briefing seminar is delivered, together with a live question and answer session. Here, participants are given a list of societal and industrial challenges provided by the research councils and sponsor companies and are required to identify novel research from SET that could address one of those challenges. This is enacted through the creation of a new venture to address the core issues and followed by weekly mentoring provided via a private Linked In forum. Participants are also encouraged to seek local support from their host university. To ensure all understand the demands of the competition and standard expected, the website contains vlogs, quotes and reflective pieces from previous participants, in addition to some examples of winning pitches.

Following the briefing session, in order to create a suitable learning environment, residential workshops are held in industry settings which enables participants to network with each other and YES stakeholders such as representatives from host organisations, business advisers, mentors, IP and patenting experts, venture capitalists et cetera (as per WEF, 2009). Over the three-day workshop period, each student group undertakes independent research whilst learning to develop a business plan and pitch for equity finance for their hypothetical firm. Each team

is supported by financial advisors, business mentors and IP experts to enable them to evaluate the feasibility and attractiveness of different commercialisation pathways. Practical advice sessions are supported by focused lectures; for example, a patent lawyer might outline the different types of intellectual property and copyright and how these can be valuable business assets in their own right describing the process, timelines and costs involved in patenting. Similarly, a venture capitalist discusses the financial projections required, the levels of return sought by investors, the different types of exit strategy that may be available and the requirements of a 'good' pitch.

Former YES participants who have subsequently started their own venture or become involved in spin-out firms in addition to other science and technology based entrepreneurs, provide guest lectures. This facilitates identification and role-modelling for the participants enabling them to learn from real-world examples about potential pitfalls and development opportunities. Given that many ECRs may be relatively isolated when working in laboratory settings, YES provides participants with the opportunity to enhance their team-working and communication skills (Webb, 2010) which have consistently been found lacking in PhD graduates by employers (Roberts, 2002; Hamouda and Treanor, 2009).

The competitive element of this intervention stimulates an 'intrinsic motivation' (Fry et al., 2008) for participants to 'want to learn' (Race, 2010) and so, develop a strong pitch that will be well regarded by not only the judging panel but also, their peers and other YES stakeholders. While the overall pedagogical approach aligns with that espoused by Gibb (1996), the teaching and learning activities resonate with those identified as 'best practice' (WEF, 2009).

Assessment of ECR presentations is undertaken by a panel comprising of a business adviser, industry expert and venture capitalist to assess the funding pitches. Successful pitches typically include a simple introduction of the industry or societal problem, their product and its benefits and USP, a competitor analysis, financial projections, IP information and patenting plans, if any, and their exit plan. All groups receive feedback on their pitches and benefit from peer learning when watching peer pitches.

4.0. Evaluation methodology

Evaluating education programmes is complex due to the differing types, objectives and methods (Ng and Feldman 2009; Fayolle and Gailly, 2015). Fayolle and Gailly (2015: 77) outline four increasingly challenging approaches to evaluation:

"The relevance of a training program (the relation between the needs and expectations of society), its coherence (whether contents, pedagogical resources and means are coherent with the objectives), its efficacy (whether the objectives have been met), and its efficiency (whether the objectives are met and resources optimized)."

Due to the longevity of YES, we have been able to draw upon evaluations undertaken at 15 and 22 years to determine its relevance, coherence and efficacy. The 15-year evaluation was externally undertaken in 2010 by Webb on behalf the BBSRC, the key sponsor, and employed a cohort analysis (comparing BBSRC funded doctoral student outcomes for those who participated in YES with those of their colleagues who did not across the 15 year programme lifespan). Two key objectives of the evaluation were:

- "An assessment of the wider benefits and impact achieved by BBSRC including detailed analysis of the qualitative benefits such as skills development and behavioural changes;
- The value for money of YES and the return on investment realised by BBSRC (taking into account quantitative and qualitative benefits and impacts)" (Webb, 2010: 1).

To address these objectives, first interviews were undertaken with

25 stakeholders. These included representatives from both the university staff involved in designing and delivering the programme and BBSRC, in addition to YES stakeholders such as: speakers, judges, mentors, university departments and technology transfer offices. Former YES participants were subsequently electronically surveyed to gather their opinions on the programme and any benefits they realised as a result of participation. Given that this was an optional programme, it could be argued that those who participated were already more entrepreneurially inclined and competent. To ascertain impact and allow for such self-selection bias, a modified version of the survey was emailed to those other ECRs eligible to participate in the YES programme that chose not to do so.

In 2017, the twenty-second year of the programme, an electronic survey link was posted in Linked In. This survey asked former participants about the knowledge, skills and experiences accrued from YES participation, if YES had increased their awareness of alternative careers, and had any influence on their subsequent career choices. Respondents were also asked about their commercialisation and entrepreneurial activities and intentions and were asked to make recommendations for improvement to the YES programme. For the purposes of this paper, in line with the 15-year evaluation, only responses from Biotechnology YES participants are considered.

Drawing from the wealth of data generated by this established initiative, we first establish the impact of the programme upon the development of entrepreneurial competences. Using the following entrepreneurial competences framework (adapted from [Rasmussen et al., 2011](#)), we explored the extent to which such competences are developed by ECRs by participating in YES.

- a) Opportunity development competency – enabling biotechnology ECRs to develop viable business opportunities
- b) Championing competency – whereby individuals develop the ability to champion the entrepreneurial process through providing meaning and energy, and,
- c) Resource acquisition competency – the need to access the resources necessary to develop new ventures.

Drawing upon the different data sources, we highlight evidence of the longer-term effect of the programme in terms of commercialisation and entrepreneurial activity outcomes. Then we examine participants' views of how YES affected their skills development and whether it had influenced the commercialisation of their research or more general entrepreneurial outcomes. In short, we sought to establish if participants attributed their longer-term outcomes to the short-term subjective measures (competence development, entrepreneurial intention or passion) engendered by YES participation.

5.0. Findings

We begin by illustrating how YES has assisted participants in developing the requisite competences for SET entrepreneurial activity; we then consider the impact that participants consider the programme has had upon their longer-term commercialisation and entrepreneurial activity.

5.1. Competency development through YES

Here, we present evidence showing how the pedagogical approach of the YES programme assists SET ECRs to develop the three specific entrepreneurial competences of opportunity development, championing competency and acquisition of resources ([Rasmussen et al., 2011](#)).

5.1.1. Opportunity development competency

Opportunity development involves the ability to develop a viable business opportunity ([Clarysse et al., 2011](#)). The YES scheme simulates

this over a three-month period commencing with the online briefing session in August, continuing through a three-day residential workshop between September and November and culminating in a grand final (for the strongest teams from each residential workshop) in December. At the briefing session, the ECRs are asked to choose from a range of 'grand' societal challenges and given guidance via an online briefing on how to seek and refine a hypothetical but plausible opportunity to address their chosen challenge. They are directed to use contemporary research breakthroughs that have not yet been commercially developed; consequently, they have to develop their knowledge of the industry needs for new technologies and also the state of the art within academe.

Following the briefing session teams are encouraged to seek advice from their local university entrepreneurship support network and also, use the private forum on LinkedIn. This iterative and Socratic approach continues at the residential workshops where they receive personal mentoring. We observe that the teams that progress to the grand final are those that are most willing to change their opportunity, based on the feedback they received from industry and academic experts. The development of a hypothetical, yet plausible, opportunity is seen to be difficult without significant interaction with the worlds of academia and industry. Teams may initially make the opportunity 'too good to be true', such as finding a cure for all cancers. However, they become well-versed in evaluating the claims of potential impact and plausibility of reported breakthroughs. Upon occasion, teams devise a novel invention with real commercialisation potential. In 2011, one team addressed the challenge of disease transmission through breastfeeding departing from the scientific literature with a novel idea for a mechanical filter. The potential for novelty was picked up via the private LinkedIn forum and the LinkedIn mentors advised the team to seek advice from their technology transfer office. As a result, the university filed a patent for the idea before participation at the workshop and publicly disclosing the idea. Using this blended learning approach ensures that technology can not only aid student engagement and preparation for participation in the YES programme, but it also protects organisers and participating teams from jeopardising real-world commercialisation opportunities.

In terms of quantifying the opportunity development competence, 30% of participants in the 2017 survey reported their YES idea as having potential, real-world commercialisation opportunity. One respondent highlighted that during the course of the workshop: "*I got an idea for a small science business – and it works.*" Another highlighted that Google are reportedly currently developing diagnostic contact lenses, the subject of their team's YES product. These examples reinforce the value of the pedagogical technique of encouraging participants to iterate between societal challenges and the science base ([Clarysse et al., 2011](#)).

5.1.2. Championing competence development

The championing competence is one that, while useful in the entrepreneurial context, benefits participants personally and in their chosen professional careers. In recognising and developing their ability to champion an idea from inception through the entrepreneurial process for the first time, many participants noted improved self-confidence. This is reflected among the following quotes from participants in the 2017 survey (see [Fig. 1](#)).

Such competence is engendered as participants adopt directorial roles within the hypothetical spin-out firm and champion this throughout the entrepreneurial process providing meaning and energy. Each team member is directed to undertake a role within the venture; whether CEO, Financial Director, Commercial and Marketing Directors, etc. this motivates an imaginative process regarding appropriate role behaviour and from whom they might seek advice. This enhances identification of skills and aptitudes for specific management functions. Support is offered for such roles through theoretical and practical discussions and bespoke mentoring i.e. each group having dedicated time with subject specialists helping to transfer subject knowledge to

Pedagogy- Content, Delivery and Learning Related

"All of the business knowledge I acquired - the process of getting funding for a start-up business, developing IP and convincing investors your business is worth their money."

"Having the opportunity to learn from successful entrepreneurs, particularly researchers that funded spin-off."

"The team work and increased confidence that I could write a business plan."

"The competitive side - getting through the rounds and improving our pitch each time."

"The entire experience was fun and grilling"

"Learning about the processes and decisions a biotech company has to consider"

"I learned most from the mentorship sessions with various professionals from industry, which were hugely helpful, especially since it was in the context of a very specific case (our proposed project). I enjoyed most the teamwork involved, as well as the friendly competition - just enough to get invested in the project but relaxed enough to allow the experience to be a fun and useful networking exercise as well."

"It was a completely different learning experience to anything I had done before. It was hard work and you were required to think differently but it was a fun 'voyage'. I would definitely recommend the scheme to others as it's a perfect opportunity to learn about business within the scientific industry."

Short-term Impacts

"I walked away from Biotech YES thinking if I wanted to start up my own business tomorrow, I wouldn't feel entirely overwhelmed."

Fig. 1. 2017 survey responses.

participants focussing on their particular idea.

This is a crucially important aspect of the YES intervention as it enables SET ECRs to make the 'mind-shift' (Downey, 2003) required to recognise opportunities for commercialisation and to successfully pursue them. One YES participant, interviewed as part of the 2017 study, who subsequently started her own business said:

"The talks that we did came from people who had started their own businesses, were quite inspirational and made you think well, I could probably do this if I have the right idea."

[Participant, 2017]

The longevity of the YES programme enables the organisers to avail themselves of a diverse range of former participants who returned as guest speakers to discuss their current careers, academic spin-outs or business ventures. For example, the founder of Puridify, a biotherapeutics start-up attracting £8m investment between 2013 and 2015, outlined how YES participation has assisted him in recognising the commercialisation potential of his research and also to create the venture. Former YES participants, who had moved into careers such as Technology Transfer Officers or Venture Capitalists, acted as mentors, speakers and judges; they also acted as examples of those who have successfully pursued alternative career pathways from that of academic research. The programme is also designed to acknowledge diversity and so draws upon speakers from a range of social and ethnic backgrounds, different SET disciplines and also women, as an under-represented group in the sector (WEF, 2009).

5.1.3. Resource acquisition competence development

YES highlights the importance of human, social and financial capital in the entrepreneurial process. The benefits of team-based entrepreneurial activity and the strategic benefits of advisory board members who can compensate for knowledge, skill, network or reputational deficiencies are frequently conveyed by guest speakers and mentors. Such networking is beneficial to participants and assists with entrepreneurial activity (Aldrich and Kim, 2007; Bienkowska and Klostsen, 2012). Resource acquisition, particularly finance, is fundamental to new venture creation (Jones, Macpherson and Jayawarna, 2013). The exposure to different finance sources, their suitability at different stages and financial planning within the YES programme was the first time the majority (84%) of participants were exposed to such topics and for many, was a critical learning point (Webb, 2010).

The value of financial awareness, an understanding of business terminology and pitching experience was considered invaluable for new venture creation. One respondent from the 2017 evaluation highlighted:

"YES raised my awareness of all that was involved in starting an enterprise from patenting to IP ... building a team, you know having done market research, a lot of things you don't learn when you're just in the lab as a scientist... You learn a lot of jargon as well that you wouldn't get exposed to just in the lab, things like exit strategies and all the financial stuff...things like that you would never learn otherwise... YES gave me a good general overview of that stuff which was really helpful when I came to start-up; I knew what knowledge and skills I needed and didn't have...I ended up doing a Masters before I started the business."

"It made me more self-confident that a career in business was not only an option but something I could excel in."

"It helped me realise the skill sets that would need improving to be able to be more successful in starting a business."

"It made me aware that I could start my own business"

Long-term Outcomes

"It spurred my entrepreneurial spirit and motivated me to start my own business"

"I have started my own biotechnology education based company."

"I created my own company"

"Now I am the owner and associate for 2 small innovation business enterprises and they have good chances to grow."

"It still encourages me to start my own business and make BOLD moves"

"I still want to start my own company and I am working on that outside of my day job"

"It totally transformed my career."

"It was my first exposure to business and it was a life changing moment for me."

"It was the first time our group had thought about commercialising science. Many of us went into the biopharma industry based on our experience winning the competition"

"Participating in Biotech YES broadened my horizons and taught me so many business skills that I still use in my job today, which I love. It wasn't the job I aspired to at the time but it's the perfect one for me."

"I now work for a biotechnology start-up company in Boston, MA, USA and I would never have known or considered a job such as the one I have now before taking part in BioYES"

"It strengthened my intention to engage in translational research and/or R&D (within academia or industry)"

"Recently I have started my spin-off company in USA"

Fig. 1. (continued)

Another former participant also recognised the importance of planned human, social and financial resource acquisition throughout their career trajectory and spin-out, highlighting in the 2017 survey:

"After completing my PhD...I went to work as a senior R&D scientist. I then went to Harvard Business School for an MBA. I worked for five years leading transactions to develop vaccines and cancer drugs. I am now an Entrepreneur in Residence at [University] while also working as the COO of a health IT company... We have raised \$10.5M+ since April 2016."

Recognising and accruing financial resources requires specific competences which inform the venture creation process. Participants were informed through short theoretical lectures of potential sources of grant funding, debt funding and equity funding, the advantages and disadvantages of each and their suitability at different stages for different purposes. This information was then illustrated by guest speakers encouraged to describe and justify their financial strategies throughout the venture lifespan with particular reference to different rounds of

funding and associated costs of the commercialisation lifecycle. In conjunction with bespoke mentoring, this enabled participants to gain an appreciation of the costs involved for successful venture creation; in addition, they were equipped with the knowledge and skills required to develop financial projections to avoid initial under-capitalisation. In undertaking this process in a safe environment, participants 'learn by doing', so facilitating entrepreneurial competence development (Neck and Greene, 2011; Fayolle and Gailly, 2015; Nabi et al., 2017).

The data suggest that resource acquisition competence was successfully developed by a number of participants. In the 2017 survey, 23% of respondents indicated they were currently involved in commercialising IP or a spin-out venture. These examples, combined with 84% of participants reporting increased awareness, knowledge and understanding of commercialisation, suggests that YES seems to have effectively facilitated the acquisition of the programme's stated learning objectives and met the overall programme aim of raising awareness of the commercialisation of ideas among SET ECRs.

"It made me realise that industry was the right career path for me. I also believe that it enhanced my CV"

"I decided to develop career in the technology transfer field. I have now managed to successfully transition to this career path."

"It reinforced that I'm more interested in biology than business so I preferred to try an academic pathway."

"After obtaining PhD I was employed in a private biotech company, where I was leading a project - numerous managerial skills learned in the YES programme came in handy. I have also co-funded a start-up that unfortunately failed due to lack of external funding – maybe next time!"

"It helped me get my current job"

"It helped me to adapt my business ideas."

"Although I am still working within academic research, the increased awareness of opportunities to spin out research has provided both impetus to pursue applicable research as well as the basic skills to get started, and this will continue to impact the path that my research takes in the future."

Fig. 1. (continued)

5.2. Impact of YES upon skills development and longer-term commercialisation and entrepreneurial outcomes

Despite the long-standing EU policy focus on equipping SET students to commercialise innovative ideas, 88% of participants in 2016 had never received formal business or commercialisation training as part of their postgraduate studies whilst 70% had never received any such training throughout any of their degree programmes. In the absence of such initiatives, YES is a rare intervention which appears to engender greater awareness of entrepreneurial opportunities and for

those who pursue them, relevant skills to support commercialisation (Webb, 2010). This is illustrated in Fig. 2.

Former participants indicated that YES significantly developed their commercial knowledge as well as financial awareness and communication skills in a commercial setting. A majority (71%) of former participants also felt that YES had significantly, or noticeably, developed their team working, management and interpersonal skills (Webb, 2010). Understandably, participants considered time management and written communication skills to be better developed through their doctoral studies, which required managing experiments, the

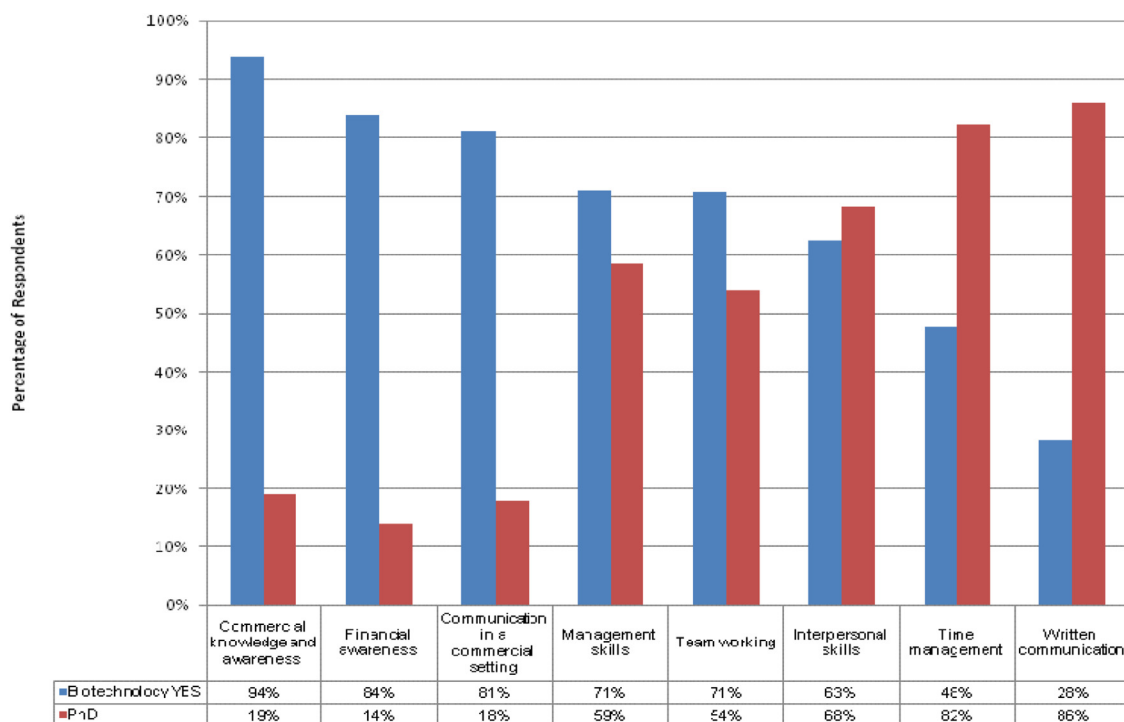


Fig. 2. Skills development attributed to YES participation by comparison to the PhD programme (adapted from Webb, 2010).

research process and writing-up their thesis, or in the case of postdocs writing academic papers, within strict timescales but over an extended period of time.

Across both evaluation exercises, YES participants claimed the programme had a positive influence upon their longer-term career aspirations and outcomes and enhanced the propensity to create their own business. In the most recent evaluation exercise in 2017, 84% of participants said YES had provided a deeper understanding of commercialisation and technology transfer. Moreover, 62% agreed that participating in YES had positively influenced their self-confidence regarding how to commercialise research or create a new venture. The magnitude and diversity of personal impact of YES participation is reflected in the quotes in Fig. 1.

The 15-year evaluation used a matched-cohort methodology to determine the longer-term impact of the programme in relation to career benefits derived by participants. These included:

- A higher proportion of YES former participants were employed within industry than their peers who did not participate
- Participants have achieved salary enhancements of up to 25%
- For those engaging in entrepreneurial activity, the programme was deemed to be highly influential in enhancing business success with up to 60% of positive performance outcomes attributed to YES.
- The financial benefits ranged from £5k p.a. of self-employed turnover to £200k of investment funding and, from one business alone, potential licensing income of three million pounds. (Webb, 2010)

Former YES participants, therefore, attribute the programme with not only engendering entrepreneurial competences but inspiring entrepreneurial ambitions that persisted over the longer-term subsequent to their participation in the YES programme. They attribute YES participation with both short-term skills and competence acquisition whilst influencing longer-term career issues such as commercialisation or new venture creation (Fig. 1). In addition to learning that strengthened competence and skills development, participants also confirmed learning in relation to self-awareness and greater reflexivity upon the strengths and weaknesses of their career aspirations. Such feedback (Fig. 1) supports the pedagogy, content and delivery mode of YES in fostering entrepreneurial competences that support longer-term entrepreneurial outcomes.

6. Discussion

This paper critically analyses the extent to which the YES programme imparts a range of entrepreneurial competences to Biotechnology ECRs with the potential to encourage and facilitate future commercialisation of their research and/or enhance their employability (Roberts, 2002). The analysis of programme evaluations and participant comments, supports the development of the three entrepreneurial competences outlined in our evaluation framework.

In terms of coherence, as outlined by Fayolle and Gailly (2015), it has been demonstrated that the YES programme is constructively aligned in terms of programme aims, learning objectives, delivery and assessment to realise desired objectives. In relation to efficacy, the evaluation findings and participant surveys demonstrate that learning and programme objectives have been met with participants reporting long term impacts on career and entrepreneurial activity from a short-term EE intervention. In terms of efficiency, ensuring objectives are met with resources being effectively utilised (Fayolle and Gailly, 2015), YES sponsors reported the 'Value for Money' derived from YES was "Very good" (Webb, 2010: 25); this perhaps explains the twenty-two year relationship with programme funders with continuing efficiency maintained through yearly financial reviews and discussions.

Entrepreneurial competence development is found to be feasible prior to direct entrepreneurial experience. Considering each competence in turn: regarding opportunity development competence,

Rasmussen et al (2011) conclude that academics who refined their opportunity through continued feedback from industrial stakeholders and academic peers were more likely to develop a spin out venture that attracted external investment. This is analogous to the evaluation data demonstrating the success rates of YES participants in gaining investment above normative rates for the sector (Webb, 2010).

Regarding the championing competence, there is evidence to suggest that science and engineering students may react adversely to social pressure in favour of entrepreneurship, even when they take courses in entrepreneurship (Maresch et al., 2016). One consideration for educators is to seek ways in which to counter the threat to social identity. Sun and Lo (2012) propose demonstrating how entrepreneurship is central to the identity of science and engineering students, for example by highlighting successful sectoral role models. As an integral part of the YES format, key role models were presented in various forms, through guest speakers either as entrepreneurs or role models of moving outside of academia as well as mentors; all providing role models of some kind. This, in addition to experiential learning, provided practical appreciation of the task at hand. Considering the development of resource acquisition competency, Landry et al (2006) extol the commercial benefit of academics extending their knowledge away from their field of specialism and interacting with researchers in other domains both within and outside academe.

The evaluation data demonstrates that the YES initiative encouraged development of knowledge-based resources beyond a participant's home discipline through three key mechanisms. First, the societal challenges posed are chosen by industry and academic experts to necessitate a cross disciplinary approach. Second, the challenges are matched to industrial innovation sites actively engaged in addressing those challenges and are hosted at industry innovation facilities such as the Stevenage Bioscience Catalyst and Unilever's Colworth Innovation Park in the UK. Third, invited speakers and mentors exhibit boundary spanning and ambidextrous behaviours indicating how this contributed to them gaining their current positions, whether that is within IP, Finance, Business Development or Regulatory Affairs.

In terms of the development of championing competence, the scheme offered effective aspirational role models as speakers, mentors and judges, all of whom were previously academic researchers that had subsequently developed successful careers in commercial domains. Such role models are said to represent the most influential group upon ECRs career intentions (Renault et al., 2016). Moreover, it was seen that as many of the speakers were past participants of YES, they could connect directly with the researchers by sharing their experiences of the scheme and explaining its contribution to realising their commercial career aspirations.

We also contribute to knowledge on the potential longevity of impacts from a short-term science and technology entrepreneurship education intervention. In so doing, we address a key weakness of much of this body of research regarding a "dominance on lower level impact measures and the lack of key detail around pedagogy" (Nabi et al., 2017: 293). Within this study, this has been addressed by expounding the pedagogical approach, teaching and learning activities and delivery mechanism, and the analysis of repeated evaluation activity due to the longevity of the programme.

6.1. Limitations

We acknowledge this study is not without its limitations. We have not assessed previous entrepreneurial exposure in participant backgrounds which may influence the effect of YES programme participation on their reported entrepreneurial competence development, given that Fayolle and Gailly (2015) found negative effects for those with prior entrepreneurial exposure. Nor have we consistently employed a control sample from the outset across all our evaluation exercises, only the 15-year evaluation by Webb (2010) used a control sample to allow for deadweight in the outcomes and impact of the programme in their

'holistic' evaluation approach (as per Pittaway and Cope, 2007). This was especially important for assessing higher level impacts (Nabi et al., 2017).

6.2. Future research directions

Future evaluations would benefit from a detailed statistical analysis and longitudinal tracking study of cohorts post-programme to ascertain short-term competence development and longer-term commercialisation and entrepreneurial activity. This would be ideally complemented by baseline data collection of pre-programme conditions such as previous entrepreneurship education and entrepreneurial exposure (family members etc.) and incorporate a control group for longitudinal follow-up also (Eesley et al., 2012).

There is an opportunity to explore the interplay of gender and entrepreneurship education on competence development and subsequent entrepreneurial activity. Women are reportedly under-represented in academic spin-outs, commercialisation and business start-up (Wynarczyk and Marlow, 2010). Yet, 52% of YES participants were female [representative of their share of postgraduate study] thus, a gendered analysis would be efficacious to assess if such programmes can help to address the current imbalance in entrepreneurial behaviour. This could be complemented by an exploration of whether the impact of this EE programme in terms of a range of entrepreneurial outcomes is gender-specific and for which outcomes in particular (Nabi et al., 2017). Such research could also inform future programme delivery (Jones, 2014).

More broadly, this study suggests that short-term, non-compulsory, entrepreneurship interventions can aid SET students in developing entrepreneurial competences and provide the inspiration for subsequent entrepreneurial activity (Souitaris et al., 2007). Future research exploring differing durations and formats with different disciplinary cohorts at undergraduate and postgraduate levels would be useful in assessing the broader efficacy of this design and delivery framework, and highlight differences in student learning needs at different levels and in different disciplines.

7. Conclusions

Acknowledging the need to develop entrepreneurial competences among post-graduate SET researchers to promote longer-term commercialisation (Thune, 2010), equip them for their future careers (Hayton and Parker, 2019) and maximise return-on-investment (Bienkowska et al., 2016; Muscio and Ramaciotti, 2019), this study provides evidence regarding the effectiveness of tailored entrepreneurship education for SET ECRs. While Brentnall et al. (2018) question the European Commission's promotion of business-plan competitions as good practice exemplars of entrepreneurship education, this paper contributes to an evidence-base showing that such competitions can effectively develop entrepreneurial competences among participants.

This paper also addresses whether long-term entrepreneurial outcomes can be fostered through such short-term interventions (Fayolle and Gailly, 2015). We outline how YES participants attribute the exploitation of opportunities for commercialisation, later in their careers, to YES participation and the competences developed therein. Due to the longevity of YES, we are able to demonstrate how such longer-term impact can be evaluated whereas the time-lag between SET research and subsequent commercialisation has previously constrained such evaluation.

We, therefore, answer calls for effective pedagogical approaches and delivery mechanisms to be explicated (Nabi et al., 2017), showcasing the efficacy of the tailored pedagogical aspects of the YES programme for developing longer-term entrepreneurial outcomes through short-term competence development (Fayolle and Gailly, 2015). We outline how YES provides online mentoring to self-selected teams who

are supported by bespoke resources on the website and, in a 'flipped classroom' approach, undertake much of the initial reading and research in a self-directed fashion. YES then culminates in a competitive, residential event which draws upon recognised good-practice approaches to effective entrepreneurship education, including: inspirational speakers, meeting entrepreneurs, business mentor sessions and peer-learning in an experiential learning environment.

While this research provides practical guidance for entrepreneurship educators, it also has implications for policymakers, Universities and SET faculty. Previous research has established that postgraduate research students are interested in learning about commercialisation and willing to spend additional time undertaking such learning (Dooley and Kenny, 2015; Muscio and Ramaciotti, 2019). The imperative, therefore, lies with Universities and policy-makers to fund and facilitate access to such interventions. The latter will require a change of attitude among some SET faculty who consider time outside the lab or away from doctoral research to be a distraction (Dooley and Kenny, 2015; Muscio and Ramaciotti, 2019), as opposed to an essential learning intervention to equip post-graduate researchers for their future careers in an increasingly-competitive labour market.

CRedit authorship contribution statement

Lorna Treanor: Conceptualization, Methodology, Investigation, Writing - original draft. **Hannah Noke:** Conceptualization, Writing - review & editing. **Susan Marlow:** . **Simon Mosey:** Conceptualization, Writing - review & editing.

Supplementary materials

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