

Entrepreneurial Characteristics in STEM: A Higher Education Institution Perspective

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Abstract

The benefit of entrepreneurship and innovation within the STEM subjects is not in question, with national bodies and academic research, expanding within the topic (RAEng 2015). The existence of entrepreneurship education and support within Higher Education Institutions (HEIs) is also increasing, although not necessarily within all subject areas (Young 2015). With often limited resources to integrate entrepreneurship education and support into STEM, is there an entrepreneurial characteristic profile that can be targeted? Are these student profiles attracted to certain topics within the STEM arena? By answering these questions, the enterprise resources of HEIs can be better allocated (but not limited to) to those individuals with increased entrepreneurial potential.

This paper presents empirical data conducted at Coventry University into the entrepreneurial profiles possessed by students within the Faculty of Engineering and Computing. The data was collected based upon the Gasse et al. (2006) Characteristic Inventory model. The data collected measures eleven characteristics such as internal locus of control, creativity, self-efficacy and risk taking propensity; all of which have significant levels of research surrounding the impact upon entrepreneurial action and intent. The results are compared across a range of samples groups that reflect disciplines within the STEM arena.

This data is discussed in the context of specific STEM topics and the potential focusing of enterprise support resources being directed towards these individuals. By targeting these engineering students further, there is a potential economic impact to business and job creation. Comparison is also drawn between the use of the Engineering Councils UK-SPEC Chartered Engineer competencies, as many of the characteristics are mirrored within the entrepreneurial characteristics measured within this research. Improved focus upon the characteristic development in areas such as leadership and tolerance to ambiguity, can be implemented further within engineering curriculum.

1. Introduction

Within Higher Education (HE) the focus upon the need for students with an understanding of enterprise and entrepreneurship has been highlighted within multiple key reports (Andersson et al. 2014; Curth et al. 2015). Yet there are areas of HE that have less enterprise and entrepreneurship engagement, such as engineering (Hill 2014). Therefore this paper looks to evaluate the different discipline segments of under graduate engineering students, in relation to entrepreneurship. Within the range of engineering disciplines for mechanical to design, each may invoke an image of a certain type of individual with specific characteristics, the research will highlight the differences between the differing types of engineering students.

The measure of entrepreneurship to be used is not the stereotypical 'has this person ran a business', as it is known that being a business owner is regular appearance in entrepreneurial behaviour, but not a mandatory one (Koh 1996; Stokes and Wilson 2010). Rather this study breaks down what it means to be entrepreneurial into eleven entrepreneurial characteristics (Gasse et al. 2006), and measures these through quantitative research methods to establish which characteristics stand out within certain disciplines and which disciplines have the most significant levels of the characteristics. Whilst entrepreneurship in engineering may not be as well integrated as it could be, the existence of these characteristics arise in multiple engineering based reports from the Engineering Council and the Royal Academy of Engineering, as well as the UK Standard for Professional Engineering Competence (UK-SPEC)(Engineering Council 2011). These associations are drawn out within the literature review.

2. Literature Review

Whilst there is some discussion as to the most appropriate word to encompass the characteristics that make up an entrepreneurial individual, such as a characteristic, trait or attribute (Stokes and Wilson 2010; White et al 2010), there is high degree of similarity between them. The QAA (2012) for example highlights a number of key behaviours, attributes and skills that account for key entrepreneurial characteristics that include opportunity recognition, self-confidence, perseverance, internal locus of control, action orientation, innovation/creativity, approach to management and decision making. The characteristics have been echoed within multiple self assessment questionnaires designed to measure entrepreneurial mind-sets, from both Gasse et al. (2006) and Caird (1993). Gasse et al. (2006) focuses upon twelve characteristics that include all those discussed by the QAA. However one characteristic discussed by Gasse was the need for challenge, which has yielded little further research to justify its inclusion. From another perspective, Caird (1993) focuses upon a narrower view of the characteristics of enterprising people, which include risk taking propensity, creative tendency, locus of control and motivation. Whilst this method has seen much usage within the enterprise education field, the narrow field of view limits the feedback to users. Following the review of these self assessment methods, Gasses method will be discussed in the research methods section in order to outline the process implemented within the study. The following paragraphs discuss the characteristics (derived through Gasse's method) backgrounds both generally in the context of entrepreneurship and more specifically with engineering demographics.

2.1. Action Orientation

Having an idea is one thing, but without taking some form of action toward that idea leaves an unanswered opportunity. For this reason the ability for entrepreneurial individuals to take action is essential, both to start businesses but also to take action in other organisational contexts (Crant 2000). Similarly to business, being an engineer also requires an action orientated mindset to take problems and put into action solutions. Rodrigues and Rebelo (2013) highlighted the importance of software engineers being action orientated, as it acted as an indicator towards their future job performance being increased. The UK-SPEC suggests two key competencies to meet the Chartered Engineer standard that highlight the need for a action orientated mind-set:

- "Ensure that variations from quality standards, programme and budgets are identified, and that corrective action is taken." (Engineering Council 2015: 26)
- "Set targets, and draft programmes and action plans." (Engineering Council 2015: 25)

2.2. Creativity

The connection between creativity and entrepreneurship is clear throughout the literature (see Rae 2007; Robinson 2006). Whilst businesses can be established by following structure, such as the processes imposed in many franchise models, creativity can be considered a key element that takes a business wit limited potential and opens avenues for diversification and growth.

As with other characteristics discussed within this literature review, creativity appears within multiple competencies listed to meet the Chartered Engineer status in UK-SPEC. These competencies are shown below:

- "Engage in the creative and innovative development of engineering technology and continuous improvement systems." (Engineering Council 2015: 25)
- "Use imagination, creativity and innovation to provide products and services which maintain and enhance the quality of the environment and community, and meet financial objective." (Engineering Council 2015: 29)

2.3. Independence

The need for independence is often a characteristic that is associated with popular entrepreneurs, who venture into business as a 'lone wolf' to deliver solutions to the masses (Cooper and Schindler 2001). Often one of the motivations behind going into business initially is linked to the pull factor that independence presents, being your own boss and leaving the restraints of employment (Kuratko et al 2001). Yet as ventures grow, the need for support and additional stakeholders within an organisation, dilutes the independence that an entrepreneur can achieve.

There is greater debate as to whether engineers can be characterised as desiring independence. Within a study of college students (Brown and Joslin 1995) it was established that the students had a significantly lower need for independence, when compared to those students in other disciplines. Despite this, research undertaken into professional engineers in a later stage of their careers, independence arises as a key factor into whether they remain in engineering (Jackson et al. 1993). Unlike many of the characteristics discussed within this literature review, the need for independence does not appear clearly within UK-SPEC, which draws parallels with Brown and Joslin (1995).

2.4. Internal locus of control

As with creativity, internal locus of control forms a substantial level of research within the entrepreneurship discussion (see Rotter 1966; Leone and Burns 2000; Caird 2013). The prominent name in the topic, Rotter (1966) discusses internal locus of control as a characteristic that gives individuals the ability to perceive a positive outlook upon changing the events around them. This ability is key to the establishment of businesses, but also forms a key element of the challenges that engineers undertake. The other side of the locus of control scale is external locus of control, which puts an individual into a mindset that suggests that events and other factors cannot be impacted by their actions.

Understandably an engineer must also hold a degree of internal locus of control thinking, in order to develop solutions that can be applied. As well as being able to impact upon problems, having an internal locus of control associates with proactive personal development too, as to effectively move forward the belief that it is possible is essential. As it is unlikely that any engineer will automatically cover all of the UK-SPEC competencies, having an internal locus of control relates to achievement of all of the competencies. Internal locus of control also can be seen more specifically within the competencies below:

- “Strive to extend own technological capability” (Engineering Council 2015: 24)
- “Broaden and deepen own knowledge base through research and experimentation. Engage in formal post-graduate academic study. Learn and develop new engineering theories and techniques in the workplace. Broaden your knowledge of engineering codes, standards and specifications.” (Engineering Council 2015: 24)

2.5. Leadership

Whilst entrepreneurs that remain as sole traders may display personal leadership, as responsibility grows within an organisation an entrepreneurial individual needs to demonstrate effective leadership over teams. Painoli and Losarwar (2012) describe the entrepreneurial leader as someone who not only manages a team, but brings groups of people together in order meet a common vision through committed effort.

A review of UK-SPEC demonstrates 14 references to leadership (and its synonyms) within the assessment competencies. Below is a selection of these competencies:

- “Lead work within all relevant legislation and regulatory frameworks, including social and employment legislation.” (Engineering Council 2015: 28)
- “Identify, agree and lead work towards collective goals.” (Engineering Council 2015: 28)
- “Lead and support team and individual development.” (Engineering Council 2015: 27)
- “Lead teams and develop staff to meet changing technical and managerial needs.” (Engineering Council 2015: 27)

2.6. Need for achievement

Another highly researched characteristic associated with the entrepreneurial mindset, is that of need for achievement. Discussed at length by a number of key scholars (see McClelland 1987; Perry et al. 1986; Klyver et al. 2007) the need for achievement is based around the achievement of goals and the potential recognition that can accompany that. Mathieu and St-Jean (2013) further discuss the need for achievement and its association with narcissistic views of these individuals.

The achievement of the Chartered Engineer status is an achievement in itself and therefore suggests there is a need for achievement within those engineers that strive for that level. However the extent to which the need exists is not clear within UK-SPEC or the broader engineering literature, especially at University level.

2.7. Opportunity recognition

Strongly attached with the creative process, the recognition of opportunities that present themselves is essential to the entrepreneurial method (Rae 2007). Not only to establish businesses, but also effectively develop and grow as an individual outside of the working environment. Baron describes the process as “connecting the dots” (2006: 108), and therefore once a pattern of cognition is established, it can become habitual to repeat the pattern.

Within UK-SPEC the need for engineers to recognize opportunities is highlighted in a number of the competencies, examples of which are shown below:

- “Identify potential projects and opportunities.” (Engineering Council 2015: 25)
- “Prepare, present and agree design recommendations, with appropriate analysis of risk, and taking account of cost, quality, safety, reliability, appearance, fitness for purpose, security, intellectual property (IP) constraints and opportunities, and environmental impact.” (Engineering Council 2015: 25)
- “Identify constraints and exploit opportunities for the development and transfer of technology within own chosen field” (Engineering Council 2015: 25)

Despite the competencies suggested by UK-SPEC discussed above, Park (2005) notes that the average engineer does not have the tendency for opportunity recognition. Rather they need to actively develop the process or form partnerships with others.

2.8. Perseverance

Eisenberger (1992) discusses the process of perseverance as one that utilises effort to achieve a goal, whilst overcoming a multitude of factors and adversity. Through the development of SMEs, adversity is a familiar term that often appears, therefore require this perseverance to continue to accomplish the goals and continue forward when the process is difficult. Van Gelderen (2012) cites the story of Sir James Dyson and the development of his dual cyclone technology into the mainstream vacuum cleaner market.

Engineers like Dyson might be considered as needing an increased level of perseverance, however the literature joining these two groups is limited and no direct reference is made with UK-SPEC. Harris (1994) indeed does present empirical research that suggests students studying engineering at HE level do hold increased levels of perseverance, which was further clarified by Brown and Joslin (1995). These approaches however did not take into account inter-discipline differences across engineering as a whole.

2.9. Risk taking propensity

An individual’s assessment of risk and decisions based upon that assessment, are discussed heavily within the entrepreneurship literature. This is not surprising given the original meaning of the word entrepreneur by Cantillon, as someone who takes upon risk in order to potentially achieve a return on investment (Thornton 1998). Brockhaus and Horwitz (1986) goes further, discussing the importance of recognising the probability factor within a decision and whether the probability of reward outweighs the initial risk.

Luthje and Franke (2003) look specifically at the risk taking of engineering students and their future intentions towards starting a business post-graduation, and in line with the theory those with higher levels of risk taking are more inclined to starting a business in the long term. Whilst the taking of risks is not focused upon primarily within UK-SPEC, there are four competencies that refer to risk and its effective management:

- “Prepare, present and agree design recommendations, with appropriate analysis of risk.” (Engineering Council 2015: 25)
- “Define a holistic and systematic approach to risk identification, assessment and management.” (Engineering Council 2015: 26)
- “Raise the awareness of risk.” (Engineering Council 2015: 27)
- “Develop and implement appropriate hazard identification and risk management systems and culture.” (Engineering Council 2015: 28)

2.10. Self-efficacy

The belief and confidence that an individual has toward their own abilities to accomplish a task, is an important one in both entrepreneurship as a whole, as well as narrower fields such as engineering. Self-efficacy (also referred to as self-confidence), is a cognitive dimension that like locus of control, relates to the control an individual wields over themselves (Rotter 1966).

As a part of UK-SPEC, there is an individual competency that directed relates to the self-efficacy:

- “Be confident and flexible in dealing with new and changing interpersonal situations” (Engineering Council 2015: 28)

2.11. Tolerance to ambiguity

The ability for individuals to manage uncertain situations is important for the process of starting a running a business as events often can differ from the initial plan (Furnham and Ribchester 1995). As situations vary with the environment and decisions by others, an effective entrepreneur can manage the high and low events, and effectively continue to produce results, whether others may lose momentum.

Within higher education generally, El-Gohary et al. (2012) highlights that the competencies that should be developed during the education process is the ability to cope with uncertainty. Despite this focus within higher education, a focus upon the characteristic within UK-SPEC is not clear (compared to the clarity of connections discussed in previous sections).

2.12. Summary

A number of the characteristics discussed within this literature review as being associated with entrepreneurial personalities, share resemblances with the competencies required to be assessed as a Chartered Engineer. As well as this, these characteristics have been shown to be important to the process of starting a business and turning ideas into economic impacts. The literature suggests that yielding these characteristics can in many cases have a positive influence upon an engineer, although this may not always be the case. In order to assess the level of these characteristics within engineering students of varying disciplines the approach discussed within the next section was adopted.

3. Research Methodology

Following the discussion within the literature around differing measurement techniques of these entrepreneurial characteristics, the decision was taken to base this research upon the validated methodology proposed by Gasse et al. (2006). This methodology presents a series of statements with attached four point Likert scales for respondents to respond with strongly agree, agree, disagree, strongly disagree. The forced nature of these scales aligns also with Caird’s General Enterprise Tendency test, that provides responded with a true/false two point Likert scale. Whilst the framework presented aligns with the supporting entrepreneurial characteristic research in the field, minor adjustments were made to the questionnaire tools to suit the sample groups and the objectives of the research.

Firstly on initial pilot testing of the questionnaire with engineering students, the matter of vocabulary was risen. The initial test presented by Gasse was designed with business orientated individuals in mind, therefore presenting many of the statements with terms such as business, enterprise and commercial. Whilst these are not foreign words to the engineering community to be questioned, the feedback from pilot test participants was that by changing words such as business to project would disguise the entrepreneurial topic being assessed through the statements. Another change to the research methodology was the number of statements to be responded to, based upon the feedback from pilot test participants. Whilst the original assessment tested the existence of need for challenge, these questions amongst others lengthened the overall

assessment to a level that was suggested as potentially off putting the students taking it un-incentivized. The final questionnaire that was released to the respondents was 33 statement long (based around the entrepreneurial characteristics) with supplementary questions to segment the participant demographics. Following the distribution of the self assessment questionnaire 452 engineering students responded fully.

4. Results and Discussion

The results gathered using the method discussed in the previous section is presented below based upon the highest levels of the characteristics measured. Whilst this research categorised the student sample into 18 disciplines, table 1 highlights the disciplines that achieved the highest result within each of the characteristics measured.

Manufacturing	Communication Management	Architecture	Design
Action Orientation	Internal Locus of Control	Independence	Self-efficacy
Creativity	Leadership	Tolerance to Ambiguity	
Need for Achievement	Opportunity recognition		
Perseverance	Risk taking propensity		

Table 1 Characteristic top results

The greatest proportion of the characteristics shared within the engineering disciplines were the Manufacturing and Communication Management students, sharing the highest scores for four of the characteristics each. For manufacturing students it is a positive results to see these characteristics being identified, with elements such as action orientation and creativity being recognised as an important competency within UK-SPEC. Despite the lack of clear mention within UK-SPEC, need for achievement and perseverance is also noted as being important in a long term perspective for these students (Harris 1994).

The Communication Management students also claimed a high score with four of the characteristics. Whilst the Manufacturing students yielded an en equally high number of the characteristics results, the characteristics that the Communications Managements students displayed have a deeper connections with the UK-SPEC competencies, with each having one or more competencies that directly relate. The other two course disciplines that claimed the highest characteristic results were Architecture and Design students. These characteristics again share resemblance with the competencies seen within UK-SPEC, as well as other literary works that suggest the positive employability impacts upon professional engineers. For example based upon Jackson et al. (1993) work, the architecture students may enjoy a longer working period within the sector, based upon increased level of independent working.

Whilst graphs were created for each of the characteristics measured within this study, due to space restrictions a summary graph is presented in Figure 1. The graph demonstrates characteristic results gathered through the self assessment methodology.

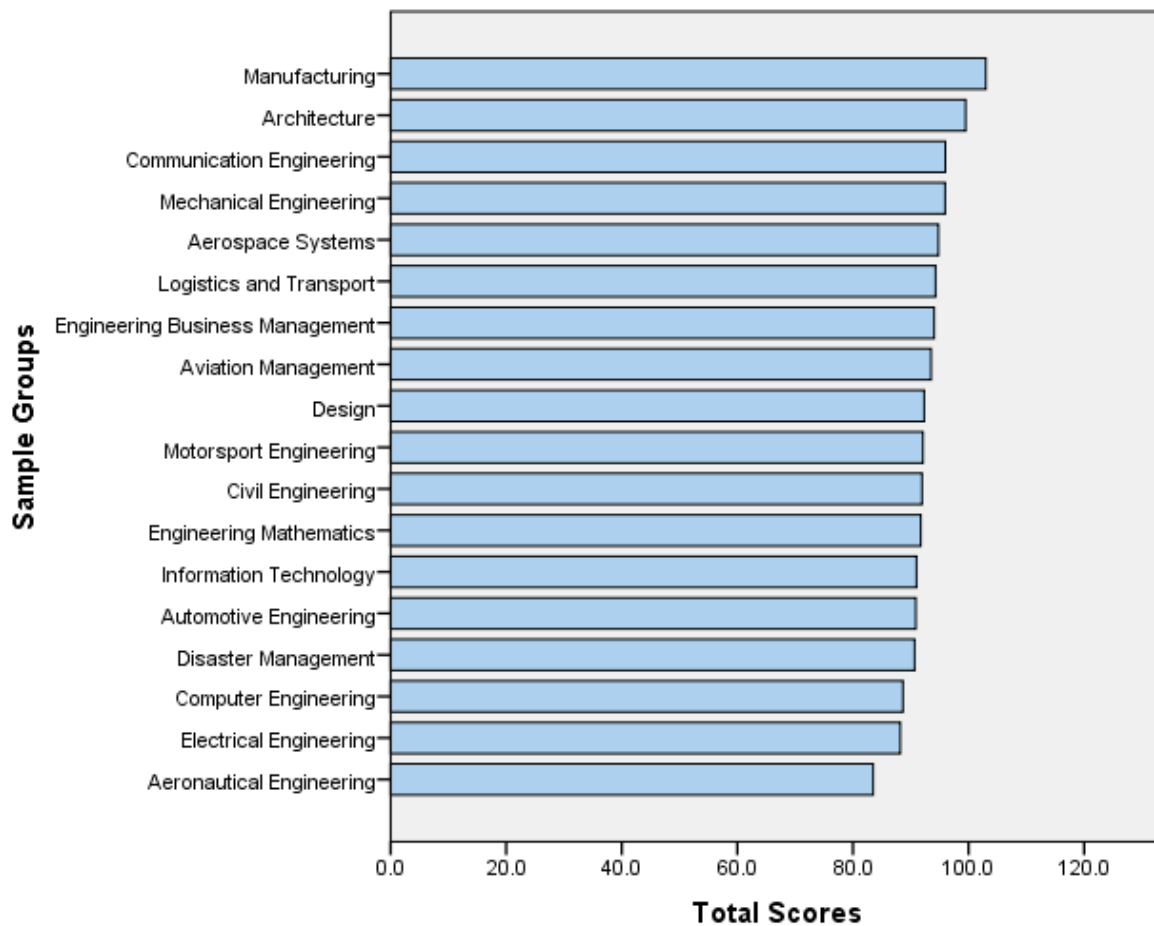


Figure 1 Mean entrepreneurial characteristics results graph

Based upon these results, this paper suggests a potential connection and learning point that can be taken from these Manufacturing and Communication Management students. Notably, there are many factors that will impact upon these students to mould their mind-sets and the characteristics that they possess, such as upbringing and culture. But the key learning point for future changes to practice is learning from the pedagogies that are seen within these disciplines. Do the lecturers themselves impress their own characteristics upon students. Given the overall mean value of characteristics displayed by the Manufacturing, Architecture and Communication management students shown in Figure 1, engineering faculties globally could potentially develop their curriculums further to be in line with both the characteristics discussed in documents such as UK-SPEC. Added to this further development of the mind-set of an entrepreneur, which will increase the propensity for business start ups, as well as the development of existing business through an intrapreneurial focus (Pinchot 1985). A key element that stood out within this data was the low level of creativity within disciplines such as Design. Whilst the Design students appeared within the middle range of the total results, the creativity level, was expected to be higher given the types of activities undertaken within their curriculum.

5. Conclusions

This paper recommends a number of opportunities for both practices within the Higher Education sector as well as wider policymaking for engineering education. As suggested throughout the literature review, the characteristics considered to be those that make up an entrepreneurial individual, are also considered desirable in a non-entrepreneurial sense, especially in reference to the competencies assessed through the Engineering Councils UK-SPEC and other key engineering reports. Therefore the development of these characteristics and attributes, should be developed further to account for the variations within the various disciplines. The results recommend that engineering faculties within this institution could considered the

pedagogical approaches of fellow teaching peers and the topics themselves in order to assess potential developments that may readdress the perceived imbalance of characteristics within the study.

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