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The Entrepreneurial Engineer: An Investigation into the Relationship between Humanitarian Engineering and Entrepreneurship

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PhD

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To my family, for always supporting me and encouraging me when times were tough. Mum & Dad, you have always supported everything I have undertaken, and without your consistent positivity and love, I would not be the man I am today.

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Dedicated to Jen, Emilia, Mum & Dad…

Jen & My Emilia.

The ladies I love and my motivation for all that I do.

Mum & Dad.

Everything I am, I owe to you. I cannot thank you enough.

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Glossary

ABS	Association of Business Schools
CBHA	Consortium of British Humanitarian Agencies
ELHRA	Enhancing Learning and Research for Humanitarian Assistance
EWB-UK	Engineers Without Borders UK
GVA	Gross Value Added
HEIs	Higher Education Institutions
NGO	Non-Governmental Organisation
RAEng	Royal Academy of Engineering
RedR	Register of Engineers for Disaster Relief (original meaning, however this is no longer in use)
UCL	University College London
UK GDP	United Kingdom Gross Domestic Product
UK-SPEC	UK Standard for Professional Engineering Competence

Abstract

'Humanitarian Engineering' (engineering to support society) is an initiative that has seen considerable growth in recent years within Australasia and North America and more recently within the UK. It is however still in a nascent phase, and is without a clear global definition.

Entrepreneurship on the other hand is well established, understood and has been researched globally for several decades, although still presents conflicting views of what it means to be entrepreneurial.

Entrepreneurship does not, on the surface, appear to share obvious connections with humanitarian engineering, however, when considering the researched characteristics of entrepreneurial individuals such as creativity, perseverance and risk taking and characteristics shown by humanitarian engineers, similarities can be seen. The purpose of this research is to develop a clear definition for the term 'Humanitarian Engineering' and to investigate rigorously the relationship between entrepreneurial characteristics and the characteristics of those studying humanitarian engineering; both qualitative and quantitative data will be used.

Qualitative data are gathered from individuals engaged in humanitarian engineering and provides insight into the definition of humanitarian engineering in a UK context.

The primary quantitative research method is an updated version of Gasse and Tremblay's (2006) Entrepreneurial Characteristic Inventory that measures the 11 recognised entrepreneurial characteristics. This allowed the author to compare and contrast these characteristics as demonstrated by students studying general engineering, humanitarian engineering and enterprise.

The quantitative results show that seven of the 11 entrepreneurial characteristics measured are significantly higher in humanitarian engineering students compared with the general engineering students. Nine of the eleven characteristics measured are significantly higher in enterprise students compared with the humanitarian engineering students.

Entrepreneurial characteristics are important within engineering, due to the economic impact and association with competencies listed within UK-SPEC to meet Chartered Engineer status but engineers are often the least engaged with entrepreneurial support packages in Higher Education Institutions (HEIs).

This research shows that engagement in humanitarian engineering activities by graduates can act as an indicator for employers of engineers, during the recruitment process, to the existence of these desired entrepreneurial competencies.

Further impact of this research is the potential targeting of students within HEIs for enterprise support mechanisms to increase venture start-ups and enhance the relationship between engineering faculties and the enterprise agenda.

1. Introduction

This chapter introduces the reader to the key concepts to be discussed within this thesis, humanitarian engineering, enterprise and entrepreneurship. The aims and objectives outline the overall premise of this study.

According to the Royal Academy of Engineering, engineers deliver solutions to problems through the use of creativity to make or improve things. These solutions are delivered throughout all sectors and affect the lives of individuals and communities globally (Watson *et al.* 2015). The economic impact of engineering industries have been estimated to contribute approximately £280 billion in gross value added (GVA) in 2011 (Rosemberg *et al.* 2015). Engineering impacts a broad range of stakeholder's socio-economic levels, however there are some economic levels that have difficulty in accessing these engineering impacts, such as those within the aerospace industry. The impact upon these engineering solutions upon the users is designed to be beneficial, however in some cases the solutions being implemented can impact negatively upon lives (Watson *et al.* 2015). This is where humanitarian engineering can readdress the balance between user benefit and economic impact.

Given the importance of engineers to the UK economy (Rosemberg *et al.* 2015), it is essential to be educating a sufficient number of students in order to meet the UK and global requirement. Yet in recent years numerous reports and articles have been published highlighting this growing shortage (Harrison 2012; Kumar *et al.* 2015; Engineering Council 2015). Professor Perkins, Chief Scientific Adviser at the Department for Business, Innovation and Skills, highlights the importance of engineers to the UK's economic recovery and the threat of a shortage stalling the growth momentum (Burns 2013). Although this shortage appears to be a negative issue, it does highlight the projected growth of industry (Kumar *et al.* 2015), rather than simply the number of engineering graduates not satisfying the labour markets' demand.

Enterprise and entrepreneurship is a topic closely associated with business, however there are connections across higher education institutions (HEIs) as a whole (Anderson *et al.* 2014). Lilischkis *et al.* (2015) highlight the challenge faced within higher education (HE) towards integrating enterprise education into all subject areas, with managers, educators and students having reservations towards its connection with their specific topic, including engineering. With engineering bodies such as the Royal Academy of Engineering clearly supporting enterprise within its agenda, the problem exists as to develop this within engineering faculties. With a large proportion of HEIs having active entrepreneurship support departments, could the reservations discussed by Lilischkis *et al.* (2015) be overcome by targeting students who already display some of the key characteristics highlighted as making someone entrepreneurial?

Whilst engineering is clearly important, the question needs to be asked whether a solution is needed or wanted.

1.1. Humanitarian Engineering

Humanitarian engineering is a growing global movement that uses engineering expertise to resolve the disadvantage that individuals and communities face (Ong 2015). However, there are multiple terms and definitions that are associated with humanitarian engineering that provides mixed definitions and a lack of clarity (Ong 2015). With its origins in disaster and emergency relief, humanitarian engineering has grown to support millions of disadvantaged groups around the world (Mitcham and Munoz 2010). Some suggest humanitarian engineering to be the use of multi-disciplinary engineers in global scenarios to assist those in need, which has been pioneered in places such as Australia and the USA (Moskal *et al.* 2008). Having been in use in the field for many years, humanitarian engineering is not a new concept, however, with the growth of charities such as Engineers Without Borders UK (EWB-UK) and RedR, the use of humanitarian engineering is assisting HEIs globally. Through the application of knowledge students already use within their field (aerospace, mechanical, electrical, nautical, motorsport and automotive, for example), scenarios are used to push students to consider other parameters. These parameters may include, cultural issues, resources available in the geographic area, political issues, religion, logistics, sustainability and local expertise (Oregon State University 2016).

With the growth of humanitarian engineering, the debate around what it means and how it should be applied is an active one, with multiple suggested meanings (Vandersteen 2009; Vandersteen *et al.* 2009; Mitchem and Munoz 2010; Reed 2002;

Garrett 1999). The debate around the definition and further research to expand on the growing UK educational perspective is presented within this thesis (see section 2.2).

1.2. Enterprise and Entrepreneurship

The development of entrepreneurs through the current educational system within the UK has been highlighted as one with areas of excellence, as well as areas that are lacking. Anderson *et al.* (2014) discuss instances where enterprise education in higher education has shown innovative engagement methods that have included engineering, yet these remain only pockets of entrepreneurship, rather than the consistent approach that would meet the government's vision of the UK being the most enterprising global economy (BERR 2008).

As universities seek out their unique niches within the competitive market of Higher Education, being entrepreneurial and enterprising is now considered to be essential for all university students, as discussed by the Lord Young Review (2014), as to create the right attitude to enhance future employability. The report states that HEIs should provide students with "access to enterprise and entrepreneurship" and support "a growing ambition amongst young people to develop their interest in social enterprise" (Young 2014:6). This is also echoed within higher education guidance, to further develop the pedagogical approach of educators to impart the skills, attributes and knowledge needed for enterprise and entrepreneurship within students (QAA 2012).

The Oslo Agenda for Entrepreneurship Education in Europe (2006) highlights the importance of enterprise and entrepreneurship education not only within business - based education, but across a range of subject disciplines as it can enhance the effectiveness of an individual within an organisation in any sector, including engineering. The benefit of enterprise within higher education is not only to the students themselves, but also long term economic development globally (Curth *et al.* 2015). This increase in private sector business support aligns with the government's transition between public- and private sector-based economies (Lavery 2015). The students engaged with enterprise at the higher education level have increased chances of starting businesses that are more innovative than those without that background (Lilischkis *et al.* 2015). However what if the students have the characteristics of entrepreneurship without direct contact with active enterprise education? With limited teaching resources, it would be beneficial to target future enterprise education to those students who are more likely to embrace it.

What does it mean to be entrepreneurial? Richard Cantillon in the 1700s presented the term in economic literature to reflect taking risks in order to make financial gains (Thornton 1998). However, in modern academic literature the meaning is further debated between those who see it being integral to business (Hawley 1900; Hornaday and Bunker 1970) and those who consider it to be mindset and trait-driven behavior (Koh 1996; Schumpeter 2013). Whether the meaning is business or mindset orientated, entrepreneurship should exist in Science, Technology, Engineering and Mathematics (STEM) subjects, including engineering (Curth *et al.* 2015). Whilst many institutions offer entrepreneurship education, this is not widespread. Therefore the question arises as to whether, certain engineering disciplines attract and/or develop these entrepreneurial individuals?

1.3. Research Origin

As nascent concepts, the humanitarian engineering and enterprise disciplines can be seen to have a degree of overlap. A comparison of the big five entrepreneurial traits (Stokes and Wilson 2010) UK Standard for Professional Engineering Competence (UK-SPEC) (Engineering Council 2011) and the Consortium of British Humanitarian Agencies (CBHA) competency framework (Rutter 2013), highlights a number of keyword matches. As well as the existence of these characteristics within these key documents, broader humanitarian engineering-based research features more discussion around entrepreneurship and its social application (Amadei and Sandekian 2010). These differences were found to be similar to those students studying enterprise and entrepreneurship. These initial observations spawned the interest to develop research methodologies to evaluate the discipline differences and hypothesize the implications of such differences.

Another issue that has arisen between entrepreneurship and engineering disciplines within higher education (HE) is the lack of engagement between the two. Whilst HEIs are being encouraged to integrate enterprise education into the curriculum and enhance the support packages for venture creation, with only 13.3 per cent of those taking part in the 'SPEED Plus' venture creation programme being based within the Engineering and Computing faculty at Coventry University (Hill *et al.* 2014). Therefore by conducting the research into humanitarian engineering, a potential avenue for more entrepreneurial engineers could be found to target future entrepreneurial support packages.

Figure 1.1 highlights the starting point of this study, with humanitarian engineering and general engineering having documented links in technical knowledge application within HE. However the existence and level of entrepreneurial characteristics is a connection less developed within the literature and therefore a key question throughout this study. Following the development of this study, an adjusted version of Figure 1.1.1 is detailed in figure 6.1 (see section 6.1).

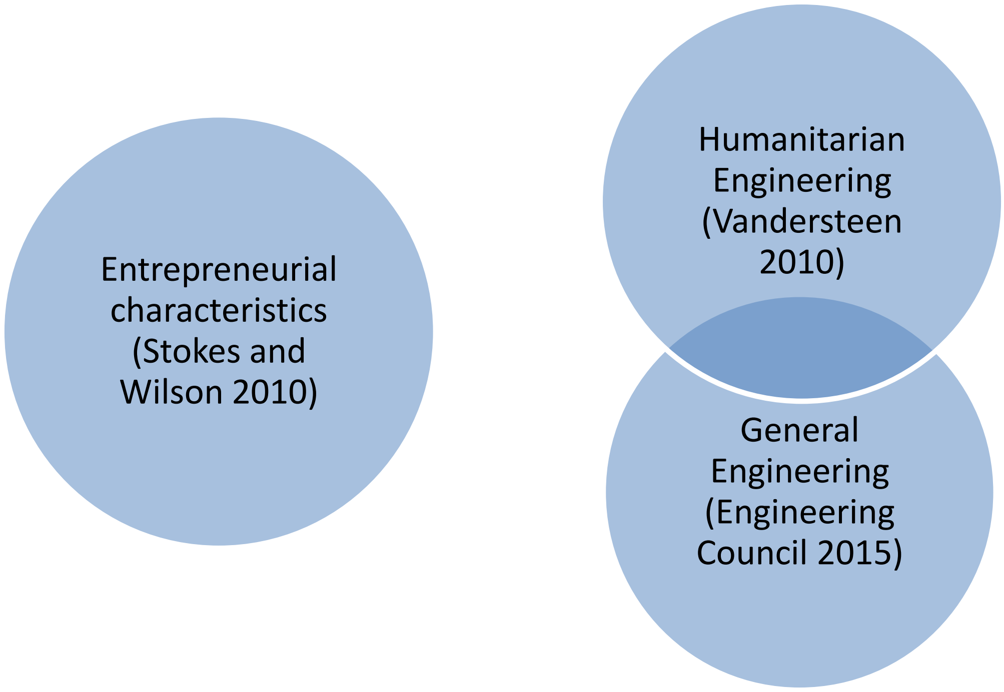

Figure 1.1 Initial association between the three core concepts of this thesis

1.4. Research Aim and Objectives

To ensure structure and focus throughout the research process, stating aims and objectives is an important step. The main aim of this research is to:

> *Critically evaluate the relationship between the humanitarian engineering discipline and entrepreneurship.*

To meet the aim of this research, the following objectives have been established to understand humanitarian engineering, its current meanings and the relationship with HE:

- Analyse the understanding of the term humanitarian engineering, of UK engineers and engineering academics.
- Critically evaluate entrepreneurial characteristics with engineering literature and the Chartered Engineer competencies within UK-SPEC.
- Critically analyse whether humanitarian engineering undergraduate students have a different level of entrepreneurial characteristics, than other engineering disciplines.
- Evaluate the implications of these characteristics upon the engineering discipline.

1.5. Thesis Plan

This thesis is divided into six chapters. The literature review (chapter 2) provides an analysis of the current literature in humanitarian engineering and entrepreneurship, to contextualise the research. Chapter 3 presents the research methodologies utilised to gather data in order to respond to the research questions proposed in section 2.4. Results are presented in chapter 4, in order to give an initial understanding of the statistical analysis and qualitative findings. These key results are then examined in greater detail and discussed within chapter 5, in which each research question is contrasted against the existent literature. This chapter evaluates the contribution to knowledge made, the implications of this research for policy and practice, study limitations and further research required. The final chapter presents the next steps for further research.

2. Literature Review

The previous chapter provides an introduction to the key concepts surrounding humanitarian engineering and entrepreneurship, in order to understand their respective impacts. It also discussed the position of this thesis within the current body of knowledge utilising aim and objectives. The purpose of this chapter is to critically evaluate the literature within the field of humanitarian engineering, entrepreneurship and engineering employability. These topics are evaluated to understand the current associations between engineering and entrepreneurship, as the current literature on humanitarian engineering and entrepreneurship is still in a nascent phase. The literature review culminates in the development of research questions to evaluate the stated aims and objectives of the study.

In order to provide a rounded literature review that addresses all of the key research surrounding the research questions, a thematic approach has been taken. As a guide for this research, the work of Vandersteen (2009) and Vandersteen *et al.* (2010) is utilised as positional research that contextualizes the literature by suggesting the broadening nature of humanitarian engineering and further allows for gaps within the literature to be defined. Similarly, entrepreneurship has been discussed in the literature as having mixed meanings, dependent upon the environment to which it is applied. Muhammad (2012) discusses entrepreneurship and the contextual background that guided his research, through an initial understanding of the entrepreneurship theory and provides further depth into the characteristics that make up the entrepreneurial mind-set. The process discussed by Muhammad has guided this literature review and supported the development of the contributions to knowledge stated further on within the thesis (see section 6.1).

2.1. Literature Sources

Compared with other subject areas such as established engineering and social sciences, humanitarian engineering and entrepreneurship are still considered to be at a nascent stage. Therefore, a broader scope is employed within the literature review to take into consideration evidence from multiple sources that represent established theories, as well as forthcoming developments in the respective topics.

The primary resource for the literature review are peer-reviewed journal articles, from the Association of Business Schools (ABS) ranked journals such as the Journal of Small Business Management and the International Entrepreneurship and Management Journal (ABS 2015), due to their peer reviewed nature. Alongside these articles, published conference proceedings from recognised conferences within the fields, such as the Global Humanitarian Technology Conference and the Institute of Small Business and Enterprise are also used to further critique current theories and highlight the context of this research. Furthermore, recent policy reports such as Engineering UK 2015 (Kumar *et al.* 2015) and the Lord Young Review (2014) are used. Publications from key organisations such as the Royal Academy of Engineering consider the goals and current focus of engineering and entrepreneurship (RAEng 2015).

A publication that is analysed throughout this literature review, as well as other chapters is the UK Standard for Professional Engineering Competence (UK-SPEC) (Engineering Council 2011). This document is used as an assessment tool to assess engineers' competencies and commitment to the engineering field, as the technical knowledge gained through a higher education degree has a need to be effectively delivered.

The literature review addresses the latest research within the themes highlighted within Figure 2.1. However, in order to provide background of the themes, seminal references are provided to give understanding of the themes' origins and theories that have remained undeveloped from their publication. Due to the nascent nature of the humanitarian engineering and entrepreneurship disciplines, an extended search is conducted to include upcoming conference papers and reports to develop theories that position the research within this thesis.

The key search themes were generated following a prior search of the current body of knowledge. Limited research has been conducted into the associations between humanitarian engineering and entrepreneurship, therefore a broader approach that looks at engineering in a wider sense is applied to establish what has been already stated.

The key themes derived from these sources to be analysed are shown below:

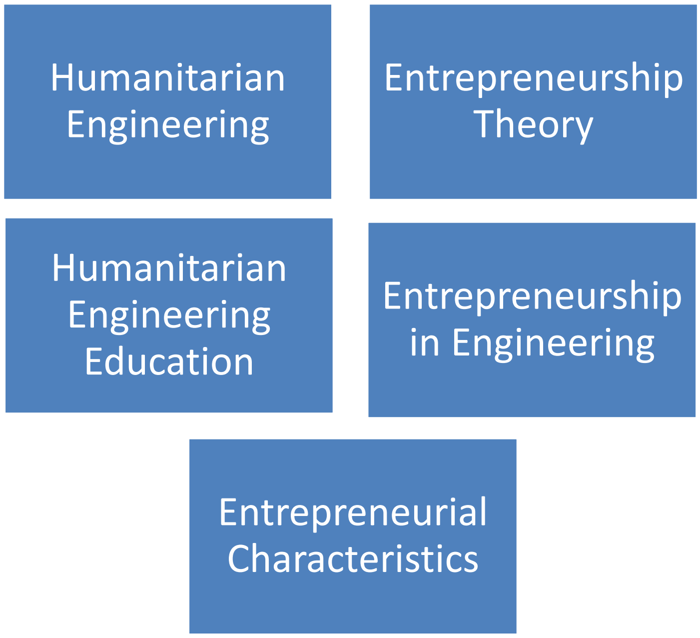

Figure 2.1 Literature review themes

2.2. Humanitarian Engineering

The term humanitarian engineering has mixed meanings to a variety of stakeholders, depending on factors that include nationality, socio-economic status, profession and culture (Vandersteen 2009; Mitcham and Munoz 2010; Ong 2015). This section looks to consider the various standpoints of these stakeholders to develop a clearer understanding of what it means to be a humanitarian engineer. Another issue that arises on initial review of the topic is the variations in terminology used to describe the use of engineering to solve social issues (Didier and Herkert 2010).

Ong (2015) argues the point that all engineers undertake their work to fulfill the needs of humans, which when compared to the dictionary definition of the word 'humanitarian' (concerned with, or seeking to promote human welfare (Pearsall and Hanks 1998)), is a valid argument. However, following research on this association, it was found that there was a more common understanding of the word humanitarian that is "to help those whose wellbeing is under threat" (Ong 2015). Whilst this is true in many engineering solutions, from the ergonomic design of a racing car, to the technology that goes into mobile phones, often these efforts are to generate revenue first and foremost. Yet that is not to say that these technologies do not impact upon those in disadvantaged positions, as has been seen within developing countries and the use of mobile phone technology to support communities economically as well as more broadly (Abraham 2006).

There are some that have argued (Amadei and Sandekian 2010) that humanitarian engineering encompasses everyone that is affected by any of the UN's eight Millennium Development Goals, which are:

- Eradicate extreme poverty and hunger
- Achieve universal primary education
- Promote gender equality and empower women
- Reduce child mortality
- Improve maternal health

- Combat HIV/AIDS, malaria and other diseases
- Ensure environmental sustainability
- Global partnership for development.

  (United Nations 2014)

Whilst the causes listed above highlight key struggles in a global context, they do not appear to combat the social issues that affect millions of people, such as the provision of shelter (Poremski *et al.* 2015). However what the goals do present is the need for the global community to support those that are disadvantaged. This disadvantage encompasses multiple issues, from those in immediate need following an emergency situation, to those that have lived with a disability and simply want to have this disadvantage rebalanced (Ong 2015).

Despite the UN's Millennium Development Goals, there are other researchers that suggest that Humanitarian Engineering should have a more generalised perspective of those individuals and communities that need help (Ong 2015; Mitchem and Munoz: 2012). Vandersteen *et al.* (2009) addresses humanitarian engineering as being:

"the application of engineering skills specifically for meeting the basic needs of all people, while at the same time promoting human (societal and cultural) development. It involved making the social consequences of technology the key constraint in the design procedure" (Vandersteen 2009:216)

Rather than only being involved in one of the many disciplines that make up engineering, such as mechanical or electrical, Vandersteen *et al.* (2009) suggest that humanitarian engineering is more of an overarching term that should form a part of every engineering discipline, as a philosophical standpoint rather than simply a topic to be covered. Despite this, there are a number of other perspectives that need to be analysed to understand humanitarian engineering fully and contribute to the overall discussion that this thesis provides.

Following an initial search of literature within the topic, two main groups emerge within the humanitarian engineering field charities including Non-Governmental Organisations (NGOs) and HEIs. Charities such as Engineers Without Borders (EWB) and RedR (Register of Engineers for Disaster Relief), stand out as leading organisations within the humanitarian engineering field. EWB is a global organisation with national bodies that focus their efforts upon developing partnerships with communities to support them in improving the quality of life, by way of engineering solutions and education. As well as this focus, EWB national bodies have been working with academic institutions to deliver widespread education within the engineering discipline, to focus up a more human-centred approach (Helgesson 2006; EWB-UK 2015).

RedR by contrast focus upon a broader approach across multiple disciplines, not just engineering. Their focus is primarily the delivery of skills, to individuals and groups to prepare for and react to disaster situations. Through this objective, RedR work to protect lives and livelihoods of people within developing countries (RedR 2015). These organisations form a part of the humanitarian engineering movement, but by no means its entirety as there are multiple factors that emerge within the literature suggesting mixed perceptions of humanitarian engineering, dependent on geography, social issues and sustainability. These factors are discussed throughout the following sections.

Working, in some instances in collaboration with these charities, HEIs are taking further steps to engage students with the humanitarian engineering agenda. In some cases this is through individual activities that give students an understanding of the area such as AirLift (developed by Northgate Games). Whilst others are more immersive in nature such as the BEng Humanitarian Engineering degree available through the University of Wales (UWTSD:2015). With a number of other examples of humanitarian engineering in academic courses (EWB:2014), the question arises as to what extent the level of depth is most beneficial to both the students and the stakeholders they impact throughout their careers.

The following sub-sections review the key literature and background of humanitarian engineering and its derivatives, to understand how academic, charity and field work has impacted upon the understanding of the term.

Reed (2002) argues that humanitarianism is grounded within the emergency disaster response sector, providing the basic needs of humans affected by disaster. These basic needs, such as; shelter, food, security, water and sanitation, are often required by large populations as a matter of urgency following an emergency (Brauman 2008; IFRC and OCHA 2015). Further discussion has been added to discuss the variables that would classify an emergency scenario as being humanitarian based or not, these include location, gender, cultural differences and political perspective (Garrett 1999). Whilst this research broadens the meaning of an emergency to encompass the factors discussed by Garrett, there are also smaller-scale emergencies internationally that could be improved or solved through engineering solutions applied appropriately. It is also important to address at this point that it is not just engineers that are needed in these situations, as when managing large populations of displaced individuals following a disaster of some form, can require information technology specialists to analyse the data and inform improved decision-making. Eggleston, cited in Ong (2015) argues that there is a continuum that exists between engineering for relief and engineering for development. Whilst both are important, often the immediate need of emergency relief can outweigh the long-term developmental needs (Ong 2015).

The populations discussed by Ong (2015) require the support of engineers to assist in problem solving and technical issues; however there are those engineers that look beyond just the headlines and seek to support any individual or community that is disadvantaged. Whilst the definition presented by Vandersteen *et al.* (2009) earlier in this section does encompass the disaster and emergency factors suggested by Reed (2002), there is a broader human requirement that opens out humanitarian engineering to a wider audience with mixed motivations to assist those needs.

The alternative argument is the broader issue of international social problems that can be witnessed globally, such as those highlighted within the Millennium Development Goals that include as health, sanitation, nutrition and shelter, which exist both inside and outside of what is deemed emergency scenarios (United Nations 2014).

Understanding where humanitarian engineering should focus, has been an area of debate between a number of authors around the topic, as evaluated in surrounding sections (Reed 2002; Ong 2015; Garrett 1999). On the side of humanitarian engineering not being limited to any geographic location sits Vandersteen *et al.* (2010). Whilst the social issues faced in countries around the world vary widely, there are problems in every community that could be improved or solved through engineering means. The reason, however, that charities such as EWB and RedR are found to work in developing countries is the level of need that can be identified in these locations.

It has been suggested that the use of humanitarian-based projects in local communities yields an improved engagement from students, due to a clearer association with their own situations, as opposed to communities thousands of miles away in a completely different situation (Vandersteen 2010). This perspective has many positive elements, not least that if a situation or case study is situated somewhere that people recognise, the wants and needs of the population as well as the external factors can be understood further by students and engineers that are geographically closer or from a similar cultural background.

However, it could be argued that this knowledge of the local environment can limit the thinking pattern of those engineers looking upon it; as they could potentially take for granted the situation and make assumptions that could cause delay, additional financial cost or even overall failure of the project itself. Within the literature around humanitarian engineering, there is no discussion surrounding emotional apathy towards the individuals and communities suffering from these issues. Does the fact that these social issues, whether local or international, are seen either in everyday life or through the media on a regular basis and society can become apathetic to the situation?

A reoccurring theme within the humanitarian engineering literature is that of sustainability through appropriate technology. Whilst the rebalancing of disadvantage is an essential process that should continue, the matter of appropriate technology usage and sustainability must be addressed. The use of appropriate technology is essential in all engineering projects, however, when focusing on those projects that have limited resources, it is even more critical due to the need to reduce wastage. An engineering project developed within Africa was the PlayPump (Chambers 2009), which despite its efforts to make pumping water a playtime activity for children, there were multiple issues that arose. The amount of play that was required to pump water into a raised holding tank was high and therefore turned what was planned to be a fun activity, into a time- and energy-consuming task. Whilst the intentions of the PlayPump were clear, a more in-depth analysis of the situation and need, may have resolved this problem prior to the development reaching a critical stage (Ong 2015).

Appropriate technologies should therefore consider the needs and strengths of the communities that they are being designed and built for, to enhance sustainability. Rather than implementing a complicated design to solve an issue, instead a simple design that can be fixed with the resources available can be as effective and more importantly having a longer lifespan. In certain instances the sustainability of an engineering solution has been developed into social enterprises within communities (Amadei et al. 2009).

A conflicting factor in whether engineering should always be integrated with humanitarian needs, is the matter of military engineering. The term engineering was established when referring to those individuals who design and build military technology (Howard and Wilson 1974; Rae and Volti 2001). This association between military technology and engineering has led to debate as to whether there are two separate sides to engineering. A key role in the modern military force is to deliver emergency response in either hostile or disaster situations. Whilst warfare has its negative connotations, it has also accelerated the development of engineering solutions in the medicine, aviation, and mining sectors (Jenkins *et al.* 2008; Agrawal 2010; Birtchnell and Gibson 2015).

The final key terminology that is regularly discussed within the literature within humanitarian engineering debates, and this is that of social justice (Kabo and Baillie 2009). Defined as the rebalancing of society to provide equal opportunities, economic and political support, social justice can be a result of effective humanitarian engineering. For example, within a village in a developing country where power is not readily available, the installation of photovoltaic cells to generate power to support learning and other basic human needs, could readdress the balance between the haves and have-nots (Adams 2007).

2.2.1. Humanitarian Engineering Education

As with many other academic disciplines, ethics plays a key role within engineering practice, and therefore must be at the forefront of engineering pedagogy (RAEng 2011). No matter what type of engineer a person is, ethical issues arise that must be dealt with effectively. Civil engineers, for example, should consider the impact of the solution being employed upon all stakeholders. However, situations where ethics have been stretched and broken has been seen with the recent Volkswagen emissions scandal (Barrett *et al.* 2015).

As a part of the promotion of ethical engineering, the Royal Academy of Engineering and the Engineering Council developed a set of Ethical Principles that engineers should abide by, some of these include:

- *"Always act with care and competence"* (RAEng 2011: 11)
- *"Keep their knowledge and skills up to date and assist the development of engineering skills and knowledge in others"* (RAEng 2011: 17)
- *"Be alert to the ways in which their work might affect others and duly respect the rights and reputations of other parties"* (RAEng 2011:29)
- *"Avoid deceptive acts, take steps to prevent corrupt practices or professional misconduct, and declare conflicts of interest"* (RAEng 2011:31)
- *"Ensure all work is lawful and justified"* (RAEng 2011:41*)*
- *"Take due account of the limited availability of natural and human resources"* (RAEng 2011:46)
- *"Be aware of the issues that engineering and technology raise for society, and listen to the aspirations and concerns of others"* (RAEng 2011:55)
- *"Be objective and truthful in any statement made in their professional capacity"* (RAEng 2011:61*)*

These guidelines present a framework for engineers to follow in order to maintain the status and reputation of engineering. However, the question arises, as to how should ethics be taught to engineering students? The following points highlight a selection of pedagogical practices used in the teaching of ethics.

Engaging students in ethics as a core part of engineering education has several purposes. Haws (2001: 223) suggests:

i) Helping students to recognise ethical issues that they may face

ii) Assist in combating uncertain situations

iii) Improve their ethical judgment.

Yet how should these points be addressed within the everyday teaching in engineering departments across the world? Lynch (1997) and Stephan (2001) both note that there are a number of methods which include:

- Independent ethics modules within engineering.
- Independent ethics modules executed in a general institution wide setting.
- Integration of ethics within each module.

Each of these delivery methods have their own advantages, therefore it is suggested that engineering education should integrate all three approaches (Martin 2005). Ethic's modules within engineering can draw on knowledge from the institutions experts, however, once completed, students may lose focus on the ethical aspect. Modules outside engineering provide a broad range of ethical dilemmas, giving students more scope; however, potentially losing focus on the engineering issues that are so important. Finally, having the degree-wide integration provides continuous mention of ethics and activities to enhance this, again this may not be given in sufficient depth for the students to fully appreciate the gravity of the issues (Newberry 2004).

Overall, ethics is clearly essential within engineering education, but are there other ways of teaching it that also engage other engineering principles and cognitive reasoning to further assist the engineers of tomorrow? Could humanitarian engineering education occupy this niche?

2.2.2. Student Employability

Alongside the educational process that HEIs put students through each year, employability must also be considered. Creasey (2013) addresses the dilemma of "how do we help our students to acquire the attributes that increase their chances of getting a job in their chosen profession?" (2013:16). It has been suggested that an active approach to getting students into the workplace and introducing them to the environments and scenarios that they are likely to face, provides an enhanced understanding for skill development (Bancino 2007). This has been likened to the benefits of engaging with topics such as humanitarian engineering, where students have the opportunity to take on scenarios out of their comfort zone; that stretch them as future engineering professionals. This use of humanitarian engineering is further detailed in the next section and backed-up with primary research in the latter stages of this thesis.

Prior to the change in tuition-fees system, it was noted in the Browne Report (Department for Business, Innovation and Skills 2010), that students were often choosing their study subject in relation to interests and expertise. However, since the tuition fee rise, students are now appearing to be making different decisions that are based upon future employability potential (Confederation of British Industry and National Union of Students 2011).

El-Gohary *et al.* (2012) highlight the importance of breaking ground on skills, attributes and behaviours early on in the education of engineers in Higher Education. Yet there can be conflict between the so-called “soft or enabling skills” and the in-depth knowledge that is required in engineering. The soft skills suggested are:

- “Ability to cope with uncertainty”.
- “Time management”.
- “Communications”.
- “Strategic thinking”. (El-Gohary *et al.* 2012:3)

Yet, El-Gohary *et al.* (2012) also discusses the hard skills that are actively sought after by employers, namely:

- “Expert qualifications”.
- “The ability to present effectively”.
- “Critical thinking and problem solving”.
- “Ability to work in a business environment”. (El-Gohary *et al.* 2012:4)

It should, therefore, be the role of engineering education at all levels not only to deliver the core knowledge of the discipline to students, but also work to nourish the soft skills that have been referred to both in academic research and industrial reports. A methodology that has been discussed as being an appropriate vehicle for developing these skill sets and implementing a number of the pedagogic practices discussed in this section is humanitarian engineering.

2.2.3. Humanitarian Engineering Case Studies

Humanitarian engineering has been recognised in this literature review as being a complex term that means many different things to multiple stakeholders. Yet it is also an area of interest within academia as both a pedagogical strategy for teaching current engineering disciplines such as mechanics, electronics and civil engineering; but also as a standalone discipline that has broad knowledge areas that can be applied in ever-changing situations (Booth 2004; Passino 2009).

In whichever form it takes, humanitarian engineering has seen a surge in popularity in recent years within the education sector, with charities such as EWB-UK and RedR at its forefront. EWB-UK has pushed to work with university students for many years in engaging them with engineering problems, which they have the challenge of solving, both in the classroom and sometimes in the field too, within international placements. The main outlet of EWB-UK within many universities across the UK is societies (or chapters) that attract student engineers, into a collaborative community. However, in recent years the concept of the EWB Challenge has been imported from EWB Australia, as a vehicle to engage more students in both mandatory and elective modules of engineering degrees.

RedR by contrast focus their energies more upon the professional engineers rather than student engineers. With a number of training programmes that assist in giving trainees a real world view of the situations faced in developing countries, often in emergency situations that are not covered in the remit of individual engineering disciplines. The influencing factors include political pressures, cultural issues and local resources (RedR 2014). Despite this training not targeting students specifically, the development of academics' understanding of these situations can have an impact upon their teaching.

Humanitarian engineering is not a movement simply developing within the UK. The USA has seen several models created to teach key principles such as appropriate technology and multi-disciplinary project management. There has been a range of integration methods from the use of humanitarian-based case studies in compulsory traditional sessions, to complete degree programme changes to focus solely on the multi-disciplinary humanitarian operations. A range of humanitarian engineering teaching activities are discussed in the following sections.

The **EWB Challenge**, developed by EWB Australia and EWB-UK, is a design project that whilst working with international case studies gives students "an opportunity to begin to develop the skills and knowledge necessary to address key global issues" (Mattiussi *et al*. 2013:2). The challenge is delivered as an information pack that provides background information on the community being assisted and the details behind the design project to be tackled. From this point academics within each institution adapts the information pack to fit with the curriculum in which it is being delivered, therefore some remain the same, and others change significantly. One of the key resources that makes the EWB challenge different to other case studies is the use of a live VLE forum based within the community itself. This enables the students to engage with an EWB volunteer in the field and gain valuable insight into the situation, therefore developing more appropriate solutions to the problems being faced (EWB Challenge 2014).

Purdue University has one of the earliest established humanitarian focused programmes in the USA (Vandersteen 2009). Their programme, entitled EPICS (Engineering Projects in Community Service) was founded in 1995 and has since developed across 17 other universities across the country (as of 2005). The primary aim is to give students the ability to use the engineering knowledge that they have gained in the classroom to deliver solutions in the local community. This process gives students the ability to both implement their learning, which in turn reinforces the teaching whilst also earning them academic credit towards their overall degree (Vandersteen 2009).

An institution seen in multiple studies in relation to humanitarian engineering (Downey *et al.* 2006; Gosinsk *et al.* 2003) is the ***Colorado School of Mines (CSM)*** which established its programme in 2003. The programme was designed to focus upon assisting in impoverished groups in other countries. The key humanitarian content is delivered as a minor element of a degree course that students can opt for throughout their time in education and includes an international placement. The primary focus of the programme is to highlight ethical issues, cultural sensitivity and financial feasibility (Moskal *et al.* 2008).

The ***University of Dayton*** developed its ETHOS group (Engineers in Technical, Humanitarian Opportunities of Service-learning) in 2001 to research the associations between engineering and a number of external factors such as politics, values and culture. A number of these external factors are discussed within the PESTLE model (political, economical, social, technological, legal and environmental) used within social science contexts. Unlike the CSM, Dayton focus upon applied research as the lynch pin of the movement, whilst integrating the findings with students through appropriate technology courses, an extra-curricular society and international placements (Eger and Pinnell 2005).

The ***Massachusetts Institute of Technology (MIT)*** introduced a series of projects in order to support students in developing appropriate technology in low-income countries. The programmes include the D-Lab (Development Lab), the IDEAS Competition (Smith *et al*. 2003) and International Development Design Summit (Greenblatt 2007).

Whilst these academic programmes provide a summary of the humanitarian movement in the USA and the UK, a more structured review of the extant literature is needed, which is thus considered within this thesis. As the EWB-UK Challenge is used as a framework to base a number of humanitarian programmes across the UK, it is essential to review its origins and the various iterations within the academic programmes across the country. Within pedagogy development, the sharing of ideas and best practice is an accepted process that can be seen in a number of the USA university examples (Eger and Pinnell 2005; Downey *et al.* 2006; Gosinsk *et al.* 2003; Vandersteen 2009); but it can now be seen with the UK too, as the EWB challenge develops.

Mattiussi *et al.* (2013) discuss the integration of the EWB Challenge into UK HEIs, from its Australian HE origins. Throughout this paper, there are multiple references towards characteristics that both the students and academic leaders presented or lacked, of which a number are also discussed within entrepreneurship literature. These characteristics (attributes) include creativity (Penaluna and Penaluna 2009), opportunity recognition (Rae 2003), self-efficacy (Bandura and McClelland 1977), action orientation (Lindgren and Packendorff 2003) and need for achievement (McClelland 1987).

2.3. Entrepreneurship Theory

Entrepreneurship has no clear definition according to many scholars, therefore causing confusion and conflict over its true meaning (Carsrud *et al.* 1986; Mitton 1989; Gartner 1988; Gartner 1990; Cunningham and Lischeron 1991; Bygrave and Hofer 1991; Bull and Willard 1993; Shane *et al.* 2003; Venkataraman 2011). The introduction of the term into economic literature can be traced back to Cantillon who is credited with its creation to describe farmers and merchants who accepted the risk of making a predefined outlay for an uncertain return in the future (Thornton 1998). The term was brought into common usage within an economic context, whilst also removing the need for business ownership as a prerequisite (Schumpeter 2013). Mill (1873) suggested that being entrepreneurial included showing direction, control, superintendence and risk-bearing, all of which are characteristics found in individuals working in a variety of fields. The evolution of entrepreneurship has seen further development in the twenty-first century, with the continued evolution of entrepreneurship education (Matlay 2005; Lilischkis *et al.* 2015).

With the evolution of the global economy, Rae (2010) has suggests that the 2008 financial crisis has created a new economic environment where entrepreneurial individuals and communities can thrive. Alongside this change, a series of dimensions have gained further importance, including emphasis on social justice (Nicholls 2010), sustainability (Parrish 2010) and the gender divide (Gupta *et al.* 2008).

The development of sustainability and social awareness within entrepreneurship, and more specifically the growth of the social enterprise movement, shares similarities with the principles of humanitarian engineering. Several of the dimensions discussed by Rae (2010) in reference to entrepreneurship, have also been found to mirror several of the essential factors discussed in the changing realm of the engineer, and these similarities are discussed further in this review. Furthermore, Gibb (2002) highlights the ability of entrepreneurial individuals not to only survive in these environments, but also make the most of the given situations. Therefore suggesting that the ambiguity of situations, such as economic recession, act as a push factor for individuals to assess new opportunities (two of the entrepreneurial characteristics to be discussed within this review).

The skills and characteristics required to be effective in these situations, have been highlighted as ones that should not be taught in a theoretical context; rather be pursued through more experiential learning methods (Hannon and Gibb 2004). This aligns with the widespread teaching strategies of Enterprise and Entrepreneurship and other subjects such as STEM, with the growth of activity- led learning (Wilson-Medhurst 2008). What is not discussed within this literature is whether experiential learning has an influence upon entrepreneurship, regardless of the discipline being taught. The development of enterprise education has also led to further research upon the students' perspective of its use in the classroom. For example, Sowmya *et al.* (2010) found a majority of students perceived enterprise education positively and saw it as a valuable addition to their curriculum. This development of entrepreneurship education has developed dedicated courses and electives that integrate within all HE disciplines, including engineering.

2.3.1. Entrepreneurship and Engineering

The association between entrepreneurship and engineering has grown to an extent where organisations such as the Royal Academy of Engineering have created their own Enterprise Hub (RAEng 2015). The Enterprise Hub provides a portal for engineers and entrepreneurs to network and develop the engineering solutions that can be developed into organisations, whether businesses, social enterprises or charities. The Enterprise Hub actively promotes the engagement of engineers to think entrepreneurially with the Africa Prize and Newton Fund. The Africa prize focuses upon rewarding innovation in a sustainable context within Africa, through an entrepreneurial focus. Whilst the Newton Fund looks to develop engineering activities within developing countries in order to develop these into sustainable ventures (RAEng 2015). Goldberg (2006) and Goffin and Carter (2011) present two sides of an argument as to whether or not engineers should be entrepreneurs. Entrepreneurs need to recognise opportunities and evaluate risks, which are undoubtedly characteristics needed within certain engineering scenarios. Yet it is argued that an engineering challenge may be so engaging that looking to a commercial end can be a distraction from the initial problem.

These developments not only demonstrate the connection between engineering and entrepreneurship, but also integrate humanitarian engineering into the discussion (see section 2.2). The focus of both the Africa Prize and Newton Fund address the need for sustainable solutions and further promote the humanitarian engineering agenda, with clear links into entrepreneurship.

Entrepreneurship is also now being found within a number of HE contexts where entrepreneurship programmes are linked to engineering courses. This increase is discussed by Souitiaris *et al.* (2007) where entrepreneurship programmes are embedded within engineering topics. The research highlights the application of entrepreneurship within an engineering context, in order to develop intentions to start a business; however, when compared to other findings from Ho and Koh (1992), starting a business is not considered pivotal in entrepreneurship. Instead there should be a greater focus upon trait theory and what position it holds within an engineering context without an implicit entrepreneurial focus. The existence of these characteristics within these engineering students is not a new concept, however, in much of the extant literature there is a narrow perspective of only one or two characteristics, rather than broader range that make up the entrepreneurial mind-set (Besterfield-Sacre *et al.* 1997; Byers *et al.* 2013).

2.3.2. Entrepreneurial Characteristics

When evaluating key authors in the entrepreneurship field (Brockhaus and Nord 1979; Koh 1996; Gurol and Atsan 2006; Stokes and Wilson 2010), it becomes evident that being entrepreneurial is not simply just starting and/or running a business, rather embracing a set of characteristics (also referred to in the literature as traits, capabilities (Obrecht 2004) and attributes) and skills that can change over time (Stokes and Wilson 2010). The Commission of European Communities (2003) highlights entrepreneurship as being a mindset that takes into account characteristics that include risk-taking, creativity and innovation. This would suggest that anyone, in any field, can be entrepreneurial or become entrepreneurial; however it is not directly stated. This, however, is not a new concept as Trait Theory highlights the different aspects of an entrepreneurial personality that has created a propensity to start a business (McClelland 1987). With entrepreneurship being argued to have foundations of these characteristics, this, therefore, suggests the question of whether certain disciplines have variations on these characteristic levels? As each characteristic is discussed in further detail within section 2.3.2, related research within the engineering discipline and each characteristic is further evaluated.

It is highlighted within trait theory that entrepreneurship comes down to characteristics, which further divide what it is to be an entrepreneur into key characteristics. The terminology used to describe the characteristics discussed by Stokes and Wilson (2010) is found to be somewhat different within other research, such as the QAA (2012) which uses the word ‘attributes’. The difference in terminology is acknowledged within this work and, from this point on, these traits and attributes, are referred to as entrepreneurial characteristics, following the path of precedents such as White *et al.* (2010) and Evanschitzky *et al.* (2015).

To demonstrate an overview of these characteristics the following table was developed by Carland *et al.* (1984) and developed further by the author to incorporate recent developments in the literature.

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Table 2.1 Entrepreneurial characteristic index Carland et al. (1984)

Table 2.1 provides a contextual summary of the key literature across the entrepreneurial characteristics, however, there are also characteristics that have lost favour within the literature. When compared to the key literature of entrepreneurial characteristics, many of these characteristics are discussed and refined to research an entrepreneurial personality that takes into consideration key characteristics (Gasse 1996; Gasse and Tremblay 2006; Mueller and Thomas 2001; Caird 1993, 2013). However, the difficulty arises when considering which of these characteristics to measure within this study. This problem is to be addressed throughout the following sections on review of the characteristics found to be dominant within the literature. Therefore a review of recognised entrepreneurship characteristics measurement methods from Caird (2003) and Gasse and Tremblay (2006) respectively, clarifies the correct mix of characteristics.

There are multiple methodologies employed in the process of measuring entrepreneurial characteristics, some of which are narrow in their focus, such as the General Enterprising Tendency Test (Caird 2013); whereas others are broader, addressing a wider range of characteristics like Gasse and Tremblay's (2006) Entrepreneurial characteristic inventory.

Caird's General Enterprising Tendency Test reviews four key characteristics (motivation, creative tendency, calculated risk-taking propensity and locus of control) that are well reviewed within the literature, yet the narrow focus leaves a gap where other well-researched characteristics should sit, such as need for achievement (McClelland 1965), tolerance to ambiguity (Furnham and Marks 1999) and self-efficacy (McGee *et al.* 2009).

Gasse and Tremblay's (2004) Entrepreneurial Inventory evaluates 12 characteristics (action orientation, creativity, independence, internal locus of control, leadership, need for achievement, need for challenge, opportunity recognition, perseverance, risk-taking propensity, self-efficacy and tolerance to ambiguity) that are considered to be entrepreneurial. This broader view offers greater detail in the individual characteristic that makes up the entrepreneurial mindset and is supported by a range of seminal literature (Rotter 1966; Bandura 1982; McClelland 1987). However, there are also questions that need to be asked in understanding its appropriateness within this study. Whilst the characteristics highlighted in Gasse and Tremblay's (2006) method first appear to follow the previous research summarised in table 2.5, the need for challenge does not appear within the searches of the entrepreneurial mindset literature.

Following the review of entrepreneurial characteristic testing mechanisms, the following sections critically review each of the characteristics associated with entrepreneurially minded individuals and evaluate whether certain characteristics are appropriate for consideration in this study. The characteristics have been chosen based upon the Gasse and Tremblay (2006) inventory, whilst removing need for challenge due to lack of supporting evidence from other literature (Stokes and Wilson 2010; Caird 2013; Muhammad 2012).

2.3.3. Action Orientation

One of the characteristics highlighted within Litzinger's (1965) research is the fact that entrepreneurs are action orientated (sometimes referred to as proactive), therefore the more they achieve the more momentum they gain. Crant (2000) defines individuals with action-orientated personalities as people prepared to "take action to influence their environments" (2000:439). Being an action-orientated individual allows for reduced constraints of external influences and with the desire to instigate environmental change (Crant and Bateman 1993; Seiebert *et al.* 2001). They also combine several other characteristics) such as opportunity recognition, the Action Orientation upon these opportunities and Perseverance often through adversity to meet objectives. They are also known to take on problems and are accountable for their actions to the world around them (Crant and Bateman 2000). An action-orientated person therefore interlinks with other entrepreneurial characteristics discussed by other academics (Kao 1989, Koh 1996, McCormack and Mellor 2002).

2.3.3.1. Action orientation in engineering and humanitarianism

Rodrigues and Rebelo (2013) discuss the effect to which having an action-orientated personality affects job performance within software engineers. The study highlights that within the software engineering field, having a proactive personality acts as a predictor upon job performance. This study is the closest discussion between action orientation and engineering, therefore there is a need to further elaborate on whether certain engineering disciplines display differing levels of action orientation.

Again, UK-SPEC is found also to highlight in two competencies the need for action within Chartered Engineers, demonstrated in the below competencies:

- "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)

The CBHA humanitarian competencies (Rutter 2011) also present a number of competencies recommended for those working in humanitarian scenarios that compare with the action-orientation characteristic. These include:

- "Able to act decisively and quickly" (Rutter 2011:6)
- "Take appropriate, co-ordinated and consistent action to handle situations of personal risk and situations of risk for others" (Rutter 2011:6)

2.3.4. Creativity

Creativity in this instance is taken to mean the process of generating ideas and innovating (Rae 2007). Whilst Rae also highlights the importance of opportunity recognition in association with creativity, this topic is discussed in more detail in section 2.3.9. Robinson (2006) suggests that creativity is a characteristic that people have from a young age; however, this diminishes with progression through the education system which requires less creativity and more rigid learning structures, such as organising facts and references in coursework and exam scenarios. Hisrich and Kearney (2013) discuss the importance of creativity as a tool for development, and this is therefore often included within business scenarios as essential to new concepts, products and services; as to adapt to the constantly changing environment. A term that is often confused with creativity is innovation. Creativity is an essential characteristic, however, innovation is the process of taking creative ideas and turning them into the processes that see the ideas provide solutions; and often create a financial reward (Holgaard *et al.* 2009).

Creativity is a complex characteristic that sits within individuals in different ways depending on several differing stimuli and influences. However, what is seen within the literature is its position both in and out of the business world (Baron and Tang 2011). This therefore is taken forward as part of this research in order to evaluate how creative tendencies play a part of the overall entrepreneurial mindset.

2.3.4.1. Creativity in Engineering and humanitarianism

Creativity is a characteristic that is actively researched within engineering, as a method of solving problems through the development of new ideas (Baille and Walker 1998; Jonassen *et al.* 2006). Bell (2014) within a Royal Academy report developed in conjunction with EWB-UK, notes the importance of creativity, especially in scenarios that that are not what would be considered normal, to break boundaries and develop solutions that are appropriate. Tierney *et al.* (1999) highlight that creativity within the engineering field is essential to economic growth and the solving of new problems. Agogue *et al.* (2015) undertook research into differences between creativity in engineers and industrial designers. The research highlighted the importance of creativity within both roles to continue to improve upon solutions in an evolving environment (Felder 1988). It was also stated that the level of creativity participants had depended upon their backgrounds. What backgrounds these individuals have are not revealed within the research, therefore suggesting a gap within the literature.

As with a number of the other entrepreneurial characteristics discussed within this review, the UK-SPEC highlights a need for creativity in two of its Chartered Engineer competencies (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)

Although it is not be possible to understand fully all potential backgrounds that support creativity, could the engagement in humanitarian engineering in HE indicate this? Furthermore, does this indicate that these students are more effectively prepared to be assessed as Chartered Engineers or effectively operate in the engineering industry?

The CBHA humanitarian competencies share parallels with creativity, these include:

- "Suggest creative improvements and different ways of working" (Rutter 2011:6)
- "Demonstrate initiative and ingenuity" (Rutter 2011:6)

2.3.5. Independence

Strongly associated with section 2.3.7 on leadership, independence (or autonomy) refers to an individual's desire to go beyond the restraints of working for others and having a greater level of freedom to follow their own leadership (Davids and Bunting 1963). On reviewing the literature, independence is suggested by academics as being a key trait of entrepreneurial individuals (Cooper and Schindler 2001).

Hornaday and Aboud (1971) analysed the levels of independence, achievement and effective leadership within a male sample group, as a method of distinguishing between entrepreneurs and non-entrepreneurs. They found that all three of these characteristics were significantly higher in entrepreneurs. However, this study focused upon primarily business owner entrepreneurs, as opposed to intrapreneurs (entrepreneurial individuals that work within large organisations). Similarly Kuratko *et al.* (2001) investigated the motivations of entrepreneur business owners, and found the desire for independence and autonomy was a high priority to them.

Despite many of the study groups shown being chosen due to their business ownership, there appears to be a lack of depth as to the entrepreneurial mindset as to the need for independence. Recruitment processes in many organisations actively promote flexibility and independence in the work place to attract these entrepreneurial candidates, and allow them to operate autonomously, which has shown to improve job satisfaction (Van Saane *et el.* 2003).

2.3.5.1. Independence in engineering and humanitarianism

Enhanced job satisfaction has been shown as a result of encouraging independent working within multiple disciplines, including engineering. Further developing this argument within the engineering discipline, it has been argued that the level of independence within engineering roles, can play a key role within the decision to enter or remain within the engineering sector (Jackson *et al.* 1993). Whilst Jackson *et al*. focused upon engineers within the working environment, Brown and Joslin (1995) note that within engineering students the level of need for independence was significantly lower than other characteristics such as perseverance. Despite these views, the existence of independence within the Chartered Engineer competencies of UK-SPEC are not clear. The focus of the chartered engineer is to consider the team and individual, this suggests that working as an individual independent unit is a key element of the profile, however this is not definitive (Engineering Council 2015). Other tenuous links could be derived from the competencies listed, however, it is not the place of this review to attach links tenuously. Within the CBHA humanitarian competency framework (Rutter 2011), there are a number of competencies that demonstrate potential links to independence, such as those listed below.

- "Show awareness of your own strengths and limitations and their impact on others" (Rutter 2011:6)
- "Seek and reflect on feedback to improve your performance" (Rutter 2011:6)

However, it is also recognised that these connections are not as clear as other competencies discussed within this thesis. The literature does not clearly identify whether independence is a key factor in engineering or engineering education. The extent to which engineering students desire independence also forms part of this research's objectives and hypotheses.

2.3.6. Internal Locus of Control

One of the most discussed characteristics to be associated with entrepreneurial behaviour is Internal Locus of Control, which has been at the forefront of entrepreneurial research since 1966 (Rotter 1966). It is defined as a personality variable that determines how an individual feels as to their control over events in their life (Leone and Burns 2000). When reviewing the literature around the characteristics that make up an entrepreneur, having an Internal Locus of Control is considered to be a significant part (Ho and Koh 1992; Riipinen 1994; Koh 1996; Littunen 2000; Gürol and Atsan 2006). However Koh (1996) later argues that Internal Locus of Control cannot be considered any more important than characteristics such as self-efficacy and risk-taking propensity. Given the definition of Internal Locus of Control, it is understandable to believe that it is the gateway to the other characteristics, as without a belief that the external world can be changed, the creation of new ideas would not occur.

An individual who possesses a strong Internal Locus of Control, is more inclined to view situations in a positive and proactive manner, giving more opportunity to make changes and influence others and the events around them (Rotter 1966; Boone *et al.* 1996). In contrast, individuals with a strong inclination towards external locus of control feel inhibited by those around them and other external influences, which are not conducive to starting a business or actively influencing projects (Rotter 1966). An individual's position between internal and external locus of control has been highlighted as being affected by their own life experiences, both personally and professionally (Dyal 1984).

It is therefore considered that entrepreneurs hold an Internal Locus of Control perspective, as rather than taking the simplest route, entrepreneurs are seen to challenge the norm and push themselves beyond what others would do (Ho and Koh 1992; Hansemark 1998; Utsch and Rauch 2000; Mueller and Thomas 2001).

2.3.6.1. Internal Locus of Control in Engineering and Humanitarianism

As a psychological concept, locus of control forms a part of the engineer as it does any other career path, however the level of which this has been researched is less than within other disciplines. Keller (2012) undertook research looking at the benefits of having an internal locus of control upon engineers and scientists. This research found that those engineers and scientists who had an internal locus of control were found to yield publications and patents within five years. A separate study of engineers highlighted that those individuals with an internal locus of control displayed a correlation with higher work satisfaction (Organ and Greene 1974). These examples of locus of control within engineering suggest a benefit to engineers having the characteristic, however on review of UK-SPEC it is not directly referred to, although inferences could be made between certain competencies listed within it, these are:

- "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)

Both of these competencies (and others within UK-SPEC) highlight a need for change, which would not be possible without an internal locus of control.

Within the CBHA humanitarian competency framework (Rutter 2011), a number of the competencies suggest a need for continued development and change to maintain humanitarian scenarios. Examples of these competencies include:

- “Seek and reflect on feedback to improve your performance” (Rutter 2011:6)
- “influence others positively to achieve programme goals” (Rutter 2011:6)

The research into internal locus of control within the engineering sector is primarily focused upon engineers within industry, rather than students studying engineering. This gap raises the question as to whether internal locus of control is a characteristic displayed across all engineering disciplines, or specific areas such as humanitarian engineering within HE.

2.3.7. Leadership

Entrepreneurs are often considered to be lone individuals, pioneering new paths in an ever-changing world (Branson 2010). McCormack and Mellor (2002) suggest that truly entrepreneurial individuals may start off on their own and be capable of making progress towards their chosen goal, whether that be in their own business or not; they are much more effective when they become leaders of others. By engaging multiple individuals in a set mission, the entrepreneurial individuals can become much more efficient in their roles by managing the expectations and needs of others (Vecchio 2003; Cogliser and Brigham 2004).

Leadership characteristics have been highlighted as paramount in several studies into entrepreneurship (Vecchio 2003; Cogliser and Brigham 2004). Painoli and Losarwar (2012) note the separation between those who are leaders and nothing more, and those who combine leadership with a number of other key characteristics such as locus of control, tolerance to ambiguity and need for achievement; which creates a different form of leader. An entrepreneurial individual who possesses leadership qualities has been defined as "leadership that creates visionary scenarios that are used to assemble and mobilise a supporting cast of participants who become committed by the vision the discovery and exploitation of strategic value creation" (Painoli and Loarwar 2012: 214).

2.3.7.1. Leadership in Engineering and Humanitarianism

Every discipline requires leadership in order to develop (Daft 2014), and engineering is no exception. Yet leadership can be regarded in multiple contexts. Leadership is known commonly for the leading of groups to reach a collective goal, yet there is also a further dimension of personal leadership and directing one's own path (Mastrangelo *et al.* 2004). Bird and Shirwin (2005) highlight the first form of science and engineering with the example of Robert Oppenheimer, commonly known as the "father of the atomic bomb". Yet Oppenheimer was the leader of a team designed to overcome the scientific and engineering hurdles to reach their long-term goal.

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)

Whilst leadership does exist within engineering disciplines, it has been found that engineers are often not focused upon academic studies into the characteristic (Robledo *et al.* 2012). This is not to say that engineering and leadership do not exist together, however the level of research linking the two is limited.

Whilst leadership exists within entrepreneurial and engineering contexts, the CBHA Humanitarian competencies framework demonstrates a number of leadership-based competencies that are sought after within field work. However, unlike many of the competencies discussed previously, leadership takes the form of an overarching competency category namely “Leadership in humanitarian response” (Rutter 2011:6) and within this category a keyword competency match states the need for works to “adapt leadership approach to the situation” (Rutter 2011:7).

This study therefore addresses this issue and gives further understanding of how leadership associates with engineering students and whether leadership is different within humanitarian engineering students.

2.3.8. Need for Achievement

Another highly researched characteristic that has been closely associated with entrepreneurial behaviour is an individual’s need for achievement (McClelland 1965; Borland 1975). Similar to Locus of Control, Need for Achievement is considered by both McClelland (1987) and Rotter (1966) to be socially learned and therefore adaptable over time. This ability of both need for achievement and locus to change over time, gives further credibility to the use of entrepreneurial development in HE as there are some who stand by outdated research that suggests entrepreneurial individuals are born and not made (Lowell 1952; Perry *et al.* 1986; Klyver *et al.* 2007).

The key element to need for achievement is an individual or group's overall expectation or motive towards completion of a particular task. This motive is often driven not necessarily simply completing a task, but the desire to complete it before others, more effectively than others or more efficiently than others. Therefore referring to this move forward, individuals with this need for achievement may experience the emotional impact of success and become addicted to its influence, therefore leading to improved planning, execution and perseverance in future tasks (Hansemark 1998).

2.3.8.1. Need for Achievement in Engineering and Humanitarianism

The development of competencies to achieve Chartered Engineer status, in itself can be categorised as demonstrating a need for achievement. However, within the UK-SPEC competencies themselves it is possible to infer connections to the characteristic, however, not with any degree of clarity. Whilst the need for achievement is evident within the overall premise of UK-SPEC, Roberts (1989) instead suggests that engineering entrepreneurs do not need to have a need for achievement. The question of whether the need for achievement does exist within these engineers is one that has not been clearly answered within this literature. Therefore this question is discussed within section 5.2.5 following the analysis of the results.

2.3.9. Opportunity Recognition

In association with previous discussion of creativity, opportunity is viewed as a key part of the entrepreneurial process (Rae 2007). Singh *et al.* (1999) suggest that opportunity recognition is one of the most important characteristics held by entrepreneurs. It is often discussed that opportunities surround each of us as we live our daily lives; however, the characteristic that sets apart certain individuals is the ability to recognise these opportunities. On viewing a multitude of factors, the recognition of an opportunity is the process of “connecting the dots” (Baron 2006:108) As with many other characteristics, when this process of connecting the dots is repeated, a pattern of thought is developed.

There are a number of differing perspectives on opportunity recognition and its place within entrepreneurial mindset discussion. Throughout the discussion there is (as in entrepreneurship as a whole) a lack of consensus, and in turn, there are conflicting views (Bhave 1994; De Koning and Muzyka 1999; Sigrist 1999; Schwartz and Teach 2000; Singh *et al.* 1999).

2.3.9.1. Opportunity recognition in engineering

Although this term is essential in the development of successful businesses, the ability to recognise opportunities is paramount within the humanitarian engineering field. Within field work, engineers are often faced with problems and opportunities that are beyond their normal frame of reference, therefore requiring a different mind-set to analyse thing such as resources and situations to establish new projects.

Within UK-SPEC the need for engineers to recognise 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 positive focus demonstrated on opportunity recognition by the UK-SPEC, Park (2005) suggests that opportunity recognition is not a characteristic that is naturally found in engineers. Rather it is argued that engineers must actively learn opportunity recognition or form partnerships, in order to share another individual's opportunity-seeking tendency. These conflicting views highlight a need to respond to this, and identify to what extent undergraduate engineering students recognise opportunities in order to contribute to this debate.

2.3.10. **Perseverance**

Perseverance as a human characteristic has been in existence since the dawn of *Homo sapiens*; however as a psychological concept its origins can be traced back to Clark (1935), with much of the focus being upon cognitive perspective focusing on beliefs, thoughts and attitudes. Eisenberger (1992) initially highlighted the power of individuals to apply high effort towards a task, and in turn this impacted other elements of their lives in a mostly positive manner. Alongside this increased positive impact, it was also seen to reduce the emotional responses that are often associated with failure such as anger, blame and frustration; which has the knock-on effect of improving future perseverance (1992). Markham *et al.* (2005) share a similar perspective to that of Eisenberger, suggesting that perseverance is the process of persisting with a task, even when faced with adversity. Therefore the level at which an individual perseveres can be judged on the size of the task, whether it be simply getting out of bed in the morning or selling a revolutionary design of vacuum cleaners, when faced with rejections from across the globe and then deciding to start a standalone organisation, as Sir James Dyson did in the 1990s (Van Gelderen 2012). Given the perception of entrepreneurial activities being notoriously challenging, a clear synergy can be seen between perseverance and the entrepreneurial mindset, whether that be working business, charity or community (Markman *et al.* 2005).

2.3.10.1. Perseverance in Engineering

The extent to which perseverance is discussed within the literature in relation to engineering is limited when searching for the word and its synonyms specifically, when compared to other characteristics discussed in this study. However studies conducted by Harris (1994) note a distinct increase in the levels of perseverance within engineering students, when compared to other disciplines outside of engineering. This is not considered a surprise given the often complex nature of engineering challenges (1994). Brown and Joslin (1995) conducted a similar study comparing the key characteristics of another engineering education sample group. Their findings further highlighted that engineers had increased levels of perseverance, however, also decreased levels of independence (as discussed in section 2.3.5.1). The study will therefore look to evaluate whether the findings of Harris (2004), Brown and Joslin (1995) can vary between different engineering disciplines.

There is also a lack of association to perseverance within UK-SPEC. Tenuous links can be made between the need for engineers to work against challenges in difficult environments; however these perspectives are only subjective and not appropriate within this research.

2.3.11. Risk-taking Propensity

It has been argued that the ultimate indicator and measure of an entrepreneur is their "perception and handling of risk" (Palmer 1971:38). An individual who takes wild risks is considered a gambler, however, one who takes no risks is considered conservative. Therefore it is important here to understand the middle ground occupied by individuals who are considered entrepreneurial and take on risks, often through a process of review and analysis. The original meaning of the word entrepreneur has its roots within risk-taking propensity, highlighted as one of the definition's core components to be risk taking (Thornton 1998). Since this early recognition of the role of risk taking propensity within entrepreneurship, others have supported this including Hawley (1900) who proposes that profits are the rewards to the individual for giving themselves the responsibility of the running of the business.

Brockhaus (1980) suggests risk taking propensity should be defined as:

> *"The propensity for Risk Taking is defined as the perceived probability of receiving the rewards associated with the success of a proposed situation, which is required by an individual's [sic] before he or she will subject themselves to the consequences associated with failure, the alternative situation providing less reward as well as less severe consequences that the proposed situation" (1980:513).*

Mill (1873) appeared initially to suggest the difference between an effective manager and business owner was the person's ability to manage risk. Brockhaus (1980) went further to study the differences in risk acceptance between managers and business owners, despite the results being inconclusive. The literature therefore to support the theory of managers and business owners having differing levels of risk-taking propensity is mixed in its perceptions.

Despite the initial assumption that entrepreneurs accept risk and therefore when the risk pays off, there are large rewards; there is significant research that suggests the opposite in that entrepreneurs instead are risk adverse and only take risks following serious consideration (Brockhaus 1980; Krueger and Dickson 1994). Pascoe *et al.* (2014) suggested that entrepreneurs that have established their businesses possess a moderate level of Risk Taking, however this viewpoint was not supported by empirical evidence.

In order to analyse Risk Taking propensity further, Palmer and Wiseman (1999) developed a risk-taking model that was established by utilising the connection noted by McClelland (1965), between need for achievement and preference for moderate probabilities of success. The six variable elements suggested by the Atkinson (1957) model include:

- The subjective probability of success
- The subjective probability of failure
- The incentive value of success
- The incentive value of avoiding failure
- The achievement motive

- The motive to avoid failure (Atkinson 1957:362).

2.3.11.1. Risk-taking in engineering

The existence of risk within the engineering field is highlighted on multiple occasions within the Engineering Councils UK-SPEC. However, whilst in the discussion surrounding entrepreneurship, risk taking is considered a positive characteristic; on review of the UK-SPEC chartered engineering competencies, risk is suggested on numerous occasions to be analysed and reviewed to ensure it is kept at a minimum (Engineering Council 2015). Some of the key competencies referring to risk include:

- “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)

Unlike UK-SPEC, other research has been conducted with engineering students to identify whether their level of risk-taking propensity had a positive impact upon the them, which found that entrepreneurial intention to start a business post-graduation was increased when risk-taking propensity was higher than average (Luthje and Franke 2003). Although this study suggests risk taking is a positive indicator towards students running businesses, there is no suggestion as to the differences between disciplines and their individual levels of risk-taking propensity. This gap is therefore discussed in more detail within section 5.2.

2.3.12. Self-efficacy

Like many of the characteristics discussed within this section, self-efficacy is one often referred to when discussing the personalities and traits of entrepreneurial individuals. Interrelated with self-confidence, this is a characteristic that can actively benefit individuals both in terms of employability and personally (Bandura and Schunk 1981; Cervone 1989). Similar to locus of control, self-efficacy is a cognitive dimension that is directly related to control (Rotter 1966). It is considered to be the level to which an individual believes in their abilities to deliver on objectives set for them (Phillips and Gully 1997). There has been significant debate as to the relationship of self-efficacy within both the realms of entrepreneurship and management in a more general sense (Gist 1987; Wood and Bandura 1989; Boyd and Vozikis 1994). Despite the origins of the self-efficacy being questioned, one of the core academic perspectives that provides clear foothold in the psychological construct is presented in Bandura's social learning theory (Bandura and McClelland 1977; Chen *et al.* 1998; De Noble *et al.* 1999). Within this discussion self-efficacy is presented as being aligned with cognition, behaviour and environment; as opposed to more traditional theories that suggest behaviour as being influenced by either environmental events or internal dispositions.

2.3.12.1. Self-efficacy in engineering

Research that looked to understand whether levels of self-efficacy could act as a predictor for performance within 644 engineers and scientists, revealed multiple benefits to increased self-efficacy. The results stated that the respondents with high levels of self-efficacy predicted increased performance ratings and numbers of patents developed (Keller 2012). Whilst this research highlights the importance of self-efficacy in engineers and scientists, there is a gap where the other entrepreneurial characteristics can add further impact into job outputs. It can also be questioned as to whether these increased levels of self-efficacy are present in engineering students, within humanitarian engineering prior to graduation.

The purpose of engineering academics is to undertake two key roles within their teaching. Firstly to impart knowledge to students that is technical and forms the core of their understanding for each discipline that they undertake. Secondly, these academics should be building the self-efficacy of their students, so that not only are they knowledgeable in their field, but also have the confidence in themselves to express that knowledge (Ponton *et al.* 2001). This research demonstrates the importance of self-efficacy within engineering disciplines, however, it does not go as far as to suggest differences between disciplines such as humanitarian engineering and other engineering disciplines. Self-efficacy is echoed within one of the Chartered Engineer competencies, stating that they should:

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

Lackeus (2014) provides further evidence by undertaking a qualitative, longitudinal study of three engineering students and the multiple characteristics observed over a nine-month period. The research found increased self-efficacy and tolerance to ambiguity. Whilst this research discusses the development of self-efficacy and tolerance to ambiguity, the methodology involved engineers who were actively involved in an entrepreneurship education programme. These findings all suggest that self-efficacy is a positive characteristic within engineers, however, it does not respond to whether there is a difference between engineering disciplines.

2.3.13. Tolerance to Ambiguity

Another highly recognised characteristic of the entrepreneurial personality is an ability to manage stressful and uncertain situations, summarised as Tolerance to Ambiguity (Furnham and Marks 2013). Furnham and Ribchester (1995) define tolerance to ambiguity as "the way an individual (or group) perceives and processes information about ambiguous situations or stimuli when confronted by an array of unfamiliar, complex or incongruent clues" (Furnham and Ribchester 1995:1). Like many of the characteristics associated with entrepreneurial personalities, tolerance to ambiguity is considered on a scale. Those with low tolerance to ambiguity are affected by stress from several sources, reacting to potential threats prematurely and do not take on situations that yield further ambiguity. On the other side of the scale, those with a high tolerance to ambiguity actively seek ambiguous situations and look to challenge themselves as stress is not seen as negative emotion (1995). Norton (1975) conducted a systematic review of 125 uses of the term “ambiguous”, as like entrepreneurship and other terms discussed in this review, there is a great deal of conflict and discussion as to its true meaning.

2.3.13.1. Tolerance to ambiguity in engineering

Keller’s (2012) use of mobile survey devices allowed for three engineering student respondents to self-monitor their emotions during an enterprise education programme, which highlighted an increase of tolerance to ambiguity. However, the small sample size within this study leaves room for potential misrepresentation of the results. These participants were also engaged in enterprise education, which may be designed to develop characteristics such as tolerance to ambiguity. El-Gohary *et al.* (2012) highlight that one of the key competencies that should be developed through the HE process is the ability to cope with uncertainty.

Tolerance to ambiguity is listed within Meyer’s (2010) research, which has been utilised within the monitoring of entrepreneurship within engineers, however, no clear conclusions were made by O’Leary (2014) as to how tolerance to ambiguity could be affected by engineering modules, rather than entrepreneurship specific modules. This study therefore address whether tolerance to ambiguity is a characteristic that is shown in significant levels within the sample groups.

2.4. Summary

This review has identified a number of gaps within the literature that influence both the methodological approach and the conclusions of this research.

The initial key finding of the review is the lack of valid research surrounding the entrepreneurial characteristic, the need for challenge, proposed by Gasse and Tremblay (2004:30). Following a review of the literature, insufficient evidence supporting the need for challenge being an entrepreneurial characteristic is available, when compared to the eleven other characteristics monitored within Gasse and Tremblay's entrepreneurship inventory.

The literature surrounding humanitarian engineering presents a diverse series of definitions. However, a number of these definitions arrive from primarily Australian- and North American-based perspectives. This, therefore, presents the gap to be filled in this study, as to what the UK perception of humanitarian engineering is.

Another key gap is the lack of focus upon undergraduate engineering disciplines, with a focus upon humanitarian engineering in reference to the characteristics discussed. An understanding whether there is a difference in characteristic levels between engineering disciplines, suggests opportunities for further development within engineering education and whether students gain benefits from these characteristics. Whilst all characteristics (other than independence) are directly referred to within the CBHA Competencies (Rutter 2011), there was no research found that highlighted the connection or lack of connection between humanitarian engineering and the characteristics associated with the entrepreneurial mindset. The research questions that this study addresses are:

1. *How is the term humanitarian engineering understood by UK academics delivering the EWB-UK Challenge and engineers engaged in the humanitarian field?*

2. *Critically assess to what extent do humanitarian engineering undergraduate students possess entrepreneurial characteristics?*

The following chapters take into account the current position of the literature review in using Gasse and Tremblay's inventory as a foundation for this research and address whether individuals engaged in humanitarian engineering activities have any connection with the entrepreneurial characteristics. On establishing the entrepreneurial characteristics within the sample groups, further qualitative research is be discussed to evaluate the impacts of these entrepreneurial characteristics.

3. Research Methodology

This chapter presents the research methodology design undertaken within this research project. Each methodological approach is discussed to highlight the process taken to gain the results, as well as limitations that were overcome. In order to respond to the research questions, a mixed-methods approach was utilised, this included questionnaires, observations and interviews. This approach used both quantitative data that is statistically analysed and qualitative data that provides further in-depth meaning behind the statistical data. The chapter also presents a breakdown of the data-collection strategy, the ethical issues and how they were addressed. The closing sections discuss the data analysis procedure undertaken to base the studies discussion and conclusions upon.

3.1. Research Philosophy

Ontologically speaking this research needed to take into account the view in which the research participants perceived reality (Hill and Tiu Wright 2001). Given the multitude of influencing factors Creswell (1994) states that in any situation multiple realities exist, within the three main parties of the study, the researcher, the research participants and the audience interpreting the written outputs. The participants within this research hold a subjective perspective over their experiences and personal values, determining their responses to the research tools. Therefore, the ontology of the study requires the understanding of complex perceptions and phenomenon that take into account the various influencing factors and antecedents.

Due to this ontological position, this study took into account the multiple realities that exist within participants perceptions, in order to construct their realities based upon the world around them. The author has no pre-conceived notions of their current ontological stance.

An appropriate research philosophy highlights the perspective in which data is to be collected. Therefore, the decision toward which philosophy this study takes is considered within the discussion of both positivist and interpretivist philosophies (Remenyi *et al.* 1998). These two perspectives are implemented to take what is believed to be the true and make it epistemological (that which is known to be true).

The entrepreneurial characteristics within this research have their roots within a positivist research philosophy, in alignment with comparable studies into entrepreneurial characteristics, such as Gasse and Tremblay (2006) and Caird (2013). The positivist approach focuses upon an objective standpoint that considers the world and its phenomenon to be observed and scientifically quantifiable. The positivist approach to research design should also allow for the study to be repeated and achieve the same results.

Whilst a positivist philosophy is the foundation of this study, an element of interpretivist philosophy is also utilised to develop qualitative depth to link the quantitative results and respond to the first research question in understanding what are the perceived meanings of humanitarian engineering.

3.2. Mixed methods

The use of mixed methods provides two different perspectives in order to answer the research questions, stated within the conclusion of the literature review (see section 2.4) (Leech and Onwugbuzie 2009). Through the use of qualitative methods an understanding is developed of the first research question: "*How is the term humanitarian engineering understood by UK academics delivering the EWB-UK Challenge and engineers engaged in the humanitarian field?*" The use of quantitative questionnaires allows for statistical analysis of data that provides a definitive response to the second research question: *"Critically assess to what extent do humanitarian engineering undergraduate students possess entrepreneurial characteristics?"* The precedence for the use of quantitative questionnaire methods is set by multiple authors such as Gasse and Tremblay (2006), Muhammad (2012) and Caird (2013). The use of quantitative survey-based research within the entrepreneurial characteristic field has allowed for measurement of characteristics. (Luthans and Ibrayeva 2006; Kraus *et al*. 2012).

The use of qualitative semi-structured interviews and observations provides a subjective view of humanitarian engineering and entrepreneurial characteristics within academia and industry (for further details of the qualitative methods please see section 3.5.5, 3.5.6, 3.5.7 and 3.5.8). Qualitative data collection have been used within multiple recognised research studies within the humanitarian engineering field by researchers such as Gosink *et al.* (2003) and Vandersteen *et al.* (2009). However, within the entrepreneurship characteristic field, qualitative research appears as a secondary resource, although used by Man and Lau (2000) and Luthans and Ibrayeva (2006). This use of qualitative research within entrepreneurial characteristics has been found to add further depth and reasoning behind the possession of the entrepreneurial characteristics. The use of qualitative methods allows for triangulation and further discussion on the statistical evidence presented on entrepreneurial characteristics.

With this combination of questionnaires and semi-structured interviews, a greater overall picture is created. However, there is also the requirement to understand the weaknesses of each method, in order to take steps in the delivery process to counteract these weaknesses. These weaknesses are discussed in further detail within sections 3.7.2, 3.7.3 and 3.7.4.

Whilst using questionnaires as a standalone data collection method would simplify the process, allowing for increased sample sizes and definitive statistical analysis of the responses, it does not provide any indication as to how these characteristics are perceived within academia and industrial environments.

3.3. Research Questions

The use of research questions is debated within the methodological literature (Bryman 2007; Ogwuegbuzie and Leech 2009; Cohen *et al.* 2011), as within positivist research, a definitive answer is being sought, therefore setting research questions on the outset is an effective method of guiding the study's approach (Saunders *et al.* 2016). Yet their use in qualitative research can potentially lead the methodology along a divergent path, through the use of semi-structured interviews and observations that yield significant results that may not be relevant to the original research questions (Bryman 2007).

This research is guided by two key research questions. The first guides the quantitative research and determines a definitive answer tested through statistical data analysis (discussed in detail in section 3.6.1). The second question looks to evaluate how the answer to the first question affects participants and the stakeholders within the global economy. These research questions are:

1. *How is the term humanitarian engineering understood by UK academics delivering the EWB-UK Challenge?*
2. *Critically assess to what extent do humanitarian engineering undergraduate students possess entrepreneurial characteristics?*

3.4. Research Approach: Time horizons

In order to understand and answer the research questions, a cross-sectional approach is taken. The use of a cross-sectional approach allows the study to answer the research questions from a single point in time. The decision towards a cross-sectional approach enabled the study to reduce the potential impact of external factors that occurred over a longer period of time, which can be within social science research, where multiple variables can be difficult to control; as found through the use of longitudinal studies (Ruspini 2002; Keeves *et al.* 2006).

A longitudinal study would have its benefits if this study was designed to measure whether entrepreneurial characteristics changed during a period of studying humanitarian engineering, however it was not. This use of a longitudinal study is discussed within the further work section (see section 6.2).

3.5. Data Collection Methods

3.5.1. Samples

Three main sample groups selected as being beneficial to the process of answering the entrepreneurship research question, by means of the quantitative questionnaire are:

- Students that are studying humanitarian engineering

- Students that are studying any form of engineering, excluding those that had studied humanitarian engineering and enterprise (Control)
- Students that are studying enterprise and entrepreneurship, excluding those that had studied humanitarian engineering.

These three groups are selected to provide a comparison between the engineering students that did and did not study humanitarian engineering, whilst evaluating whether the enterprise students, as research suggests do indeed have the highest levels of these characteristics which have been shown to impact upon entrepreneurial intention. These samples are utilised to respond to the research question:

Critically assess to what extent do humanitarian engineering undergraduate students possess entrepreneurial characteristics?

Coventry University was chosen as a research focus in order to reduce potential variables within the samples. The humanitarian engineering sample group was taking part in elective modules based on the topic, in the same way in which the enterprise students were also taking part in elective-based modules. If this had not have been the case, it would not be possible to suggest that the topic of humanitarian engineering or enterprise had any effect upon the existence of these characteristics. Whilst this approach of sampling elective module students, highlights an interest within the topics, this study also understands that other factors may act upon a student choosing these modules, which may include lack of other options and peer pressure.

As a part of the qualitative data collection process a broader sample selection is used in order to respond to the research question “*How is the term humanitarian engineering understood by UK academics delivering the EWB-UK Challenge?”* The interviews also deliver a degree of depth into the existence of entrepreneurial characteristics from the participant perspective. The semi-structured interviews are conducted with:

- Academic staff that teach humanitarian engineering through the EWB Challenge
- Engineers in industry that have been previously engaged in humanitarian engineering activities
- Students engaged in humanitarian engineering teaching.

The qualitative observations conducted involve three sample groups ranked on their level of engagement in humanitarian activities. As with the interviews, the observation sample groups are observed in order to evaluate the existence of entrepreneurial characteristics within the humanitarian engineering field. The observed groups are:

- Student participants in a humanitarian engineering elective module at Coventry University
- Student participants in the EWB Challenge final event.

The final sample group that was included within this study was made up of students and academic taking part within a focus group at an EWB-UK conference event. This focus group was targeted to gain a set of discussion based considerations towards the meanings of keywords in this study, namely humanitarian engineering and entrepreneurship.

These nine sample groups, as stated, represent a progression in engagement with the humanitarian engineering agenda. The questionnaires analyse the level of entrepreneurial characteristics within three student samples, whilst the qualitative data samples provide verification as to these characteristics existing in facets of humanitarian engineering from those studying it, those that teach it within HE and engineers who have worked in the humanitarian field. The qualitative data yields further depth into the behaviours and motivations behind the entrepreneurial characteristics that the qualitative data cannot. The qualitative data adds further discussion into the meaning and interpretation of the term humanitarian engineering, from those that are actively engaged in it, either through teaching or practising it.

3.5.2. Questionnaire

The use of a questionnaire in this research process, allows for a positivist approach to answering the first research question. The ability to collect closed data on high quantities of respondents enables the researcher to conduct statistical analysis to identify the significance levels of the results and respond accurately to the research question. The high quantity of participants that can be collected through this methodology has the added benefit of being able to provide further validity and representation (Cohen *et al.* 2011).

Following a review of pre-validated entrepreneurial characteristics measurement methods, Gasse and Tremblay's (2006) characteristic inventory method was found to be most appropriate. The assessment method to come to this conclusion involved the use of literature to support the individual characteristics considered to be entrepreneurial, as well as a review of the published peer reviewed literature to validate Gasse and Tremblay's characteristic inventory. As a further verification method, during the distribution of the questionnaire participants are asked whether they previously or currently run businesses. The results of these questions are compared to the total scores for all participants, which stated that those who had business experience had statistically significantly higher total scores. This result verifies the questionnaire replicates the characteristic inventory as identifying individuals with these entrepreneurial characteristics that lead to business based intentions. Following this review, additions were made to develop the method further which is discussed further on in this section (Oppenheim 1992).

This method utilised pre-determined statements that require participants to identify their level of agreement or disagreement for each through the use of forced Likert scales (Gasse and Tremblay 2004; Caird 2013). Gasse and Tremblay's method did however display issues that were addressed prior to the use of the questionnaire. The original Gasse and Tremblay method was designed to address 12 characteristics considered to be within the entrepreneurial personality profile, however, through the literature review and comparison of other research tools, there were insufficient levels of peer-reviewed literature surrounding the "need for challenge". Due to the lack of research on this topic the question testing this characteristic was removed from the questionnaire.

Following the removal of the statements relating to "need for challenge", 33 statements remained to form the main body of the questionnaire. These statements were then combined with positional questions to identify demographic data for analysis purposes. One of the key segmentation purposes of these questions is to divide respondents that may straddle multiple sample groups, such as students that have undertaken both entrepreneurship and humanitarian engineering modules. The participants that indicated being engaged in more than one of the sample groups are removed from the overall statistical analysis carried out.

3.5.3. Pilot Testing

The use of pilot testing the questionnaire was a crucial process within this research, due to the initial consideration of adapting the original statements used by Gasse and

Tremblay (2006). The process of piloting a research tool enables the researcher to test the reliability and validity, as well as isolating other issues that could corrupt the data being captured (Rosier 1997). The original statements within the questionnaire used business-based vocabulary and due to the majority of targeted respondents coming from the engineering field, this was investigated prior to full distribution. In order to reduce this potential for bias, two pilot versions of the questionnaire were tested. The first questionnaire had its statements based around the original Gasse and Tremblay method with business vocabulary, and the second updated individual words to produce a questionnaire with a broader scope. The change in vocabulary only focused upon the words 'business' or 'enterprise' and changed them to 'project'.

Following initial pilot testing with a self-selected group of four humanitarian engineering students, the business-based vocabulary was highlighted as an area for potential bias that may lead engineering students not to relate as much to the statements. Following these initial comments from the students, comparison was made between the statements that were directed at the same characteristic, whilst being worded differently. Whilst variations did exist between the responses, with only a small sample group, the results were inconclusive. Despite this, the initial verbal responses from respondents on bias were considered sufficient evidence to utilise the updated version of the questionnaire. The 33 statements were added to the other positioning questions and presented in digital and paper versions.

The final version of the questionnaire was presented at the 2013 and 2014 Institute of Small Business and Entrepreneurship (ISBE) conference, as a working paper and full paper respectively. The papers were presented within different tracks at each conference, allowing peers to further question the methodology. On both occasions minor feedback was gained toward the papers themselves, however, none that directly affected the structure the statements being utilised. The questionnaire also contributed to a further research paper evaluating the potential impacts of entrepreneurial engineers in developing countries, which was later published in the book *Systemic Entrepreneurship: Contemporary Issues and Case Studies* (2015) The data from the research collected in this study has also been accepted for presentation within an engineering and entrepreneurship track at the 2016 International Conference for Innovation and Entrepreneurship. A full copy of the questionnaire can be found in Appendix 3.

To further evidence the validity of the quantitative research tool employed within this research another pilot test was conducted with the data, prior to comparison of the sample groups. The test performed is designed to establish whether the original purpose of the test designed by Gasse and Tremblay (2006), seeking out characteristics of those best suited to running a business, remains effective. In order to conduct this, all participants within the quantitative research were asked whether they were currently or had previously run a business. The results of this question compared against the levels of those who had and had not run businesses are compared to establish whether the tool remains effective, following adjustments previously discussed.

3.5.4. Hypotheses Testing

As a part of the positivist approach and the use of questionnaires, a series of null hypotheses are tested to be accepted or rejected. The use of hypothesis testing within the entrepreneurial characteristics topic was utilized in line with the precedent set by Koh (1996). Whilst a research question approach alone, could accomplish the objectives of this research, the use of hypothesis testing breaks down the eleven key characteristics as a part of the second research question. The use of hypothesis within this study allows for a narrowing of the second research question "*Critically assess to what extent do humanitarian engineering undergraduate students possess entrepreneurial characteristics?*" into separate phenomena in the individual entrepreneurial characteristics. With each phenomena being tested individually, it is possible to suggest potential contributing factors upon each (Saunders 2016). The use of a series of hypothesis further refines the use of a scientific method throughout the research (Kerlinger 1970).

The null hypotheses are made up of the eleven entrepreneurial characteristics (internal locus of control, creativity, tolerance to ambiguity, leadership, perseverance, action orientation, self-efficacy, independence, opportunity recognition, risk taking and need for achievement), followed by statement below:

"Internal locus of control is higher in students studying humanitarian engineering, compared to those studying other forms of engineering".

Following the statistical analysis testing, if the above null hypotheses are rejected, the alternative hypotheses below are accepted respectively:

"Internal locus of control is higher in students studying humanitarian engineering, compared to those studying other forms of engineering"

Or

"Internal locus of control is lower in students studying humanitarian engineering, compared to those studying other forms of engineering".

3.5.5. Observations

Using questionnaires is an effective method of getting participants to self-assess (Wilson 1994), yet in order to compare results with a third person perspective, an observation methodology has been implemented within the research. This difference between how participants say they feel about certain questions within a survey can differ from the actual actions of the individual (Spradley and Baker 1980; Robson 2011). For this reason, the observations within this research are used to triangulate the quantitative data gathered within the surveys, in order to gather further depth (Simpson and Tuson 2003). A systematic approach was undertaken within the observations utilising the framework presented in table 3.1, that detailed how the participants behaved within scenarios and with the artefacts given to them (Marshall and Marshall 1995, Simpson and Tuson 2003). Observations are chosen to add further depth of behavioural aspects, as unlike the surveys, observations took place within groups ranging from 30 to 50 participants. This, therefore, provides the researcher the opportunity to take note of interactions amongst other members of the groups and identify actions and behaviour that could then be compared against questionnaire results. These comparisons provide further levels of validity and discussion as to the reason for the behaviour (Marshall 1995).

The first observation sample took place within an elective module, entitled "Humanitarian Engineering". Students were observed at two stages of this session, firstly as an entire group receiving instructions from the lecturer, followed by small group work activities in groups between six and ten students in size. During the class activities, characteristic criteria highlighted in table 3.1 were used to monitor each characteristic and guide note taking across members of each student group.

The second observation sample consisted of students taking part in the EWB Challenge final event. This event brought together students and academics who had further engaged with the EWB Challenge final and submitted an entry for the final awards. The methodology in this case observed students taking part within side activities to the main presentations throughout the day and the final presentation by the winning team. The characteristic criteria discussed in the following pages (see Table 3.1) were used to guide the observation process.

An overt observation method was utilised within this study, as despite the potential benefits of covert observations, the practical and ethical implications would restrict the level of data gathered (Flick 1998). The dimension between overt and covert observation is one that has required consideration in identifying which was most appropriate, whilst also weighing up the positive and negative issues associated with both (Cooper and Schindler 2001). The use of an overt observational methodology, is one that allows for greater flexibility in that an observer can manoeuvre themselves to view developing issues as they happen (Saunders 2016) whilst a covert technique would restrict, especially if using recording devices that are fixed for the duration of the situation (Cooper and Schindler 2001). However, despite the overt flexibility, the observer cannot be in all places at all times, which may make the observer miss key information, this is an issue that was accepted as a reasonable step to take. Despite the variety of benefits and drawbacks of the use of overt and covert observational strategies, it was decided that overt both had the highest ratio of positive to negative points, was less complex in its establishment, and it held an increased ethical standpoint within the research overall (Cohen *et al.* 2011).

In order to monitor effectively the eleven characteristics discussed in section 2.3.2, Table 3.1 has been created as a framework to demonstrate the key indicators that are being observed and their academic underpinning.

Characteristic	**Characteristic Indicators**	**Theoretical Underpinning**
Action Orientation	Do participants act upon plans quickly or procrastinate and talk through the issues? "Take action and learn both from actions and active experimentation" (QAA 2012:16) *e.g. participants discuss key factors and then move to undertake a task, rather than procrastinating on trivial, non-important issues.*	Crant 1996; Filler 2013
Creativity	Do participants look outside the box to develop a response to a problem? "innovate and offer creative solutions to challenging and complex problems" (QAA 2012:16) "take creative and innovative approaches that are evidenced through multiple solutions and reflective processes" (QAA 2012:17) *e.g. are participants developing new ideas and strategies, or do they look to applying current solutions.*	Lee *et al.* 2004; Hamidi *et al.* 2008; Abdekhodaee and Steele 2012
Independence	Do participants collaborate in teams or work independently on their own? *e.g. are participants working predominantly on their own or working with others to reach a successful conclusion.*	Carter *et al.* 2003; Shediak 2014
Internal Locus of	Do participants have an optimistic or	Mueller and Thomas 2001;

Control	pessimistic view upon the activities? “recognise that they are in control of their own destiny” (QAA 2012:16) *e.g. participants may display this through engagement in a task and continue to pursue an end target despite setbacks.*	Alhuei *et al*. 2014
Leadership	Do participants demonstrate management skills over external parties? *e.g. are there certain members of groups that take charge and are the leading voice throughout a scenario?*	McCormack and Mellor 2002; Jensen and Luthans 2006
Need for Achievement	Do participants look to win, do better, quicker or more efficiently? *e.g. participants that show this might focus on running multiple simulations to find the most efficient methodology.*	McClelland 1987; Alam and Mohiuddin 2014
Opportunity Recognition	How do participants react to opportunities to take part and take advantage of scenarios presented to them? “the ability to seek out, be alert to, and identify opportunities” (QAA 2012:16) “recognise patterns and opportunities in complex situations and environments” (QAA 2012:17) *e.g. do the participants shy away from new ideas or look for new creative opportunities?*	Ozgen and Baron 2007; Brahma and Panda 2014,
Perseverance	How do participant effort levels change as activities progress? “demonstrate perseverance, resilience and determination to achieve goals, especially within challenging situation” (QAA 2012: 16)	Clark 1935; Markhan *et al.* 2005; Van Gelderen 2012

	e.g. do participants have a sustained level of focus throughout the task? Or do effort levels diminish over time?	
Risk Taking Propensity	Do participants propose radical solutions that could be considered risky? *e.g. do participants look to risk resources in order to potentially gain reward.*	Pascoe *et al.* 2014; Smith et al. 2014;
Self-Efficacy	How do participants present themselves? "enhance self-confidence and belief through practice of enterprising skills and behaviours" (QAA 2012:16) *e.g. do participants take an active role within the group, or do they shy away from presenting ideas and concerns*	Zhao *et al.* 2005; McGee *et al.* 2009
Tolerance to Ambiguity	How do participants respond to changing situations within certain tasks? *e.g. when scenarios change, do participants respond positively or negatively?*	Furnham and Ribchester 1995; Furnham and Marks 2013

Table 3.1 Characteristic observational indicator matrix

The use of this observational method is employed to provide further evidence for or against the quantitative research findings discussed in section 3.5.2.

3.5.6. Interviews

To further add to the qualitative data collected within the observations discussed in section 3.5.5, interviews were conducted in order to provide further insight into the understanding of the term humanitarian engineering and existence of entrepreneurial characteristics within students (Kvale 1996). The interviews provide a greater insight into the experiences of those engaged in humanitarian engineering activities and where entrepreneurial characteristics have presented themselves, both in the classroom, industry and humanitarian field work (Kirk and Miller 1985; Arksey and Knight 1999). Whilst the quantitative data can provide statistical evidence to respond to a hypothesis, the interviews allow for examples where these characteristics have arisen and been demonstrated. Interviews were conducted with three main samples that reflected; the student perspective of humanitarian engineering, the lecturer's perspective of humanitarian engineering education and engineers that are working within industry that had previous experience within the field. Each of the interviews averaged one hour in duration (Bogdan and Biklen 1992).

The students that were interviewed were volunteers enrolled in the second year "EWB Challenge" elective module. The academics interviewed were all active participants within the integration of the EWB challenge within their respective modules and courses from universities across the UK. These interviews were arranged in conjunction with EWB-UK in order to provide feedback from universities engaged in the challenge. This research was conducted in joint collaboration with a postgraduate student from Edinburgh University undertaking a separate study. The final selection of interviewees volunteered due to their working within industry and also having experience in the humanitarian engineering field.

The interviews were designed to be semi-structured in nature in order to allow for consistency within the key questions being asked, whilst also allowing for a degree of flexibility to further expand upon responses the participants had given to questions. The full transcripts of the anonymised interviews are available on CD-ROM within Appendix 4. Through the delivery of the interviews to the academics engaged in the EWB Challenge, a series of case studies are presented within the results chapter to outline varying models of practice.

3.5.7. Case Studies

Case studies are used in this research to establish the current state of humanitarian engineering education in the UK. These case studies are created following the interviewing of module leaders within universities across the UK that were integrating the EWB-UK Challenge into their modules. This research was conducted on behalf of EWB-UK in order to report back to them for a continuous improvement programme; whilst also working with research partners to enhance our individual educational projects.

As with other forms of qualitative methodologies discussed in this chapter, case studies provide detail and in-depth data that provides further insight into a given scenario (Saunders 2016). However, whilst the case study method is effective in presenting and representing reality, it cannot be relied on to evaluate the actions of individuals in detail, as it focuses upon snapshots of the current situation (Saunders 2016). In order to highlight the actions of research participants, the use of observational data analysis needs to be considered.

3.5.8. Focus Groups

The use of focus groups provides a further dynamic to the data collected within this study, due to their ability to generate knowledge based upon multiple views of participants (Cohen *et al.* 2011). The collection of data from focus groups, enables the individual participants the ability to discuss and share knowledge from one another, leading to broader discussion and results (Morgan 1997).

In this instance, a focus group was conducted at the 2013 EWB-UK conference at University College, London. Seven participants, with humanitarian engineering backgrounds took part in this focus group to discuss, firstly, what they understood humanitarian engineering meant to them and, secondly, to discuss the meaning of entrepreneurship and the characteristics participants understood to associate with this agenda.

3.5.9. Ethics

Following a strict ethical procedure is essential to the research process; therefore, there is a need to navigate effectively ethical issues in order to deliver answers to the research questions (Frankfort-Nachmias and Nachmias 1992). Throughout this study's project life span, there was strict adherence to Coventry University ethics processes set out within the University's guidelines (Coventry University 2016). For each individual data collection method (questionnaires, interviews and observations), a separate ethics application was made for each (copies of which can be found in Appendix 2).

Within both the quantitative and qualitative data collection processes of this study, full Participant Information Sheets were made available to participants in order to highlight the aims of the project and participant rights with regards to their data being utilised. (Please see Appendix 2 for a copy of the participant information sheet). Participants taking part within the all forms of data collection were requested to confirm their informed consent for the data to be used within this research. (A copy of the informed consent request can be found in Appendix 2.)

Following the completion of the interview transcription process, the names and other indicative information was anonymised to minimise the risk of participant identification. This process removed names, institutions and other identifying content and replaced them with bracketed items that highlight the nature of the removed material, as to maintain the context of the transcripts (Oliver 2010).

3.6. Data Analysis

As a study that utilises mixed methods, the following sections address how the data were analysed, and why these methods were selected.

3.6.1. Quantitative – Statistical analysis

In alignment with the positivist research philosophy of this study (see section 3.1), the use of statistical analysis processes provide clear responses as to whether the null hypothesis are rejected or not. The data collected is analysed solely utilising IBMs SPSS statistical analysis software package, in line with other entrepreneurial characteristics studies (Fatoki and Asah 2011; Muhammad 2012). The SPSS package is widely recognised as one of the most effective data management software packages (Bryman and Cramer 2005; Field 2009).

The use of Likert scales within the majority of the questionnaire content prompted the use of non-parametric, Mann-Whitney Independent U regression tests to determine statistical significant differences (Bertram 2007; Corder and Foreman 2009). These tests provide a probability value (P-Value) which, if this is revealed to be less than 0.05, the null hypothesis is rejected and an alternative hypothesis is accepted. Gaining statistical significance proves that chance cannot explain the results, rather that other variables are influencing the results (Kirk and Rosen 1999; Kirk 2007).

In order to address the reliability of the questionnaire and its future development, the Cronbach Alpha test was undertaken. The use of Cronbach Alpha is highlighted as being appropriate for scale-based measures specifically (Cohen *et al.* 2011). By calculating the Cronbach Alpha of the questionnaire results, it is possible to understand firstly how reliable the overall questionnaire is, as well as highlighting individual questions that may be limiting the overall questionnaire (Saunders 2016). Cohen *et al.* (2011) suggest that a questionnaire's internal reliability be considered acceptable when it is 0.6 or above. These statistical results are presented within the results chapter (see section 4.4.3).

3.6.2. Qualitative – Keyword coding

The interview and observation data gathered provides a detailed understanding to support the quantitative results after analysis. Following the completion of the interviews and observations, the data were transcribed and anonymised in accordance with the Coventry University Ethics Procedure. Using the Computer Assisted Qualitative Data Analysis (CAQDAS) software QSR NVivo 10, the transcriptions were imported and content keywords analysis undertaken (Kikooma 2010). Data on the frequency of keywords and their synonyms was generated to gain a positivist perspective from the responses that can be compared with other respondents and each of the eleven characteristics. For further depth, the transcribed data was codified to organise key responses that were integrated into the discussion (MacMillan 2005; Cohen *et al*. 2011; Saunders 2016).

3.7. Summary

Overall, the methodology utilised within this research study yields a diverse set of results that enables firm discussion and conclusions to be made. The flowchart in figure 3.1 illustrates the process taken.

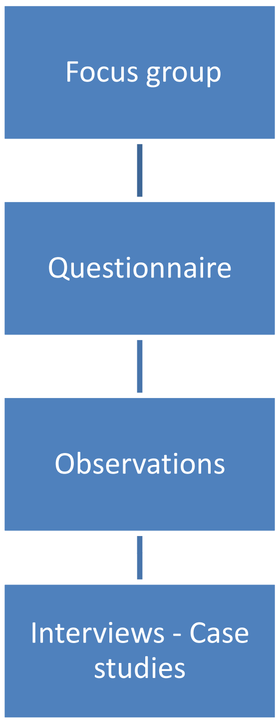

Figure 3.1 Research methodology flowchart

The methods chosen reflect preceding research conducted by others, within the humanitarian engineering and entrepreneurship field; adapted to respond effectively to the research questions. With the mix between questionnaires, interviews and observations, the different qualitative and quantitative data gives an approach that offers the strengths of both, but also requires greater understanding of their weaknesses. Further to the methodologies discussed, the secondary data collected throughout the literature review forms a base of information to identify connections and gaps within the current academic knowledge base. The following results chapter shall present the findings collected through the methods discussed in this chapter.

4. Results

Following the insight into the various research methods employed within this research project, this chapter presents the responses gained from participants. Due to the mixed methods, this chapter includes graphical representations and statistical analysis of that data, whilst also detailing the insights gained from the observations. The data collected from the interview stage of this research is presented directly within the discussion chapter and full transcripts can be found in Appendix 4.

4.1. Observations

As discussed within the research methodology chapter, observations can be a beneficial method towards understanding the behaviours and traits of participants when they are going about certain processes. The following sections highlight the observations of two sample groups; students taking part in a third year undergraduate Add+Vantage module at Coventry University, entitled ‘Humanitarian Engineering’ and students engaged in Engineers Without Borders (EWB) who attended the 2013 EWB-UK Challenge Final event. Each of these groups displayed subtle differences, however, all shared a common goal to make a difference. All of the following observations were observed using Table 3.1 (see section 3.3.5.) as a framework to structure the results.

4.1.1. Humanitarian Engineering In-Class Observations

Of the initial group to be observed, these students had chosen to study humanitarian engineering as an elective module within their third year at Coventry University. The students in this class had a mean age of 21. The point at which the class was observed came in the fifth week of the ten-week module, where they engaged in an exercise called AirLift (Northgate Training 2014) which gave the students a hands-on task that required them to use their engineering knowledge to deliver supplies to in a hypothetical disaster zone, in the most efficient way. Maximum efficiency was gained by packaging the differently shaped blocks (representing different supplies) within a finite-sized box to represent an aircraft's cargo hold; whilst devising the shortest route to benefit from the loss in weight following each drop. During the session each group was observed to evaluate the team dynamic and characteristics being displayed through the use of the framework detailed in table Table *3.1*.

Table 4.1 was developed to breakdown each of the individual in-class groups and highlight their strengths and weaknesses, with special reference to the entrepreneurial characteristics discussed in the literature review and combining the questions suggested in Table 3.1 in section 3.5.5. The words bold within the table highlight the characteristic that was identified.

Group	Strengths	Weaknesses
1	Group came up with multiple ideas prior to deciding upon the one to focus upon. ***(Creativity)*** There was a more communal feel in the group, lacking *leadership* but working together. **(Team work)**	Group struggled to gain momentum. Difficulty coming together as a group. ***(Independence)*** Once ideas were developed, feasibility was difficult to establish.
2	Quick decision making process. ***(Leadership)*** Once through the initial grasping of the challenge they began debating the main issues. ***(Perseverance)***	A slow starting group, that struggled to communicate with one and other in the initial stages. No clear ***leadership***, which led to a lack of direction and reduced levels of efficiency.
3	All members of the group working towards their own individual area. ***(Independence)*** ***Creative*** ideas being developed. Identify the opportunities that are available from the scenario. ***(Opportunity Recognition)***	Clashing between some team member due to poor communication – "to many cooks spoil the broth" Pessimistic language displayed by students. ***(Lack of Internal Locus of Control)***
4	A focused group that had defined roles and responsibilities to reach a successful conclusion. ***Leadership*** developed early to assign roles. Handled the uncertainty of changing scenarios well. ***(Tolerance to Ambiguity)***	Had trouble breaking away from engineering principles. Team started the task enthusiastically, however as time progressed a decrease in efforts was observed, compared with previous work and other groups work levels. ***(Perseverance)***
5	Focused on the identification of the scenarios needs. Use of systematic tools to deliver	Difficulty integrating between international and home students. A large amount of discussion, however a distinct level of action up until the

	the needs assessment. Developed a number of new ideas to implement and feasibility test. ***(Creativity)***	last minute. ***(Action Orientation)***
6	Developed a number of strategies to address each of the key problems in the scenario. ***(Creativity)*** Worked efficiently as a team and appointed a leader in the initial phase of the activity. ***(Leadership)*** Worked consistently throughout and regularly reviewed the status of all team members. ***(Perseverance)***	Caught up in problems that slowed the process down, where other groups did not have as much trouble. ***(Tolerance to Ambiguity)***

Table 4.1 In class observation team results

4.1.2. EWB Challenge Final – Observation

The EWB Challenge Final provided an opportunity to observe undergraduate students who had become further engaged with the humanitarian engineering movement. With students coming from across the United Kingdom, to demonstrate their solutions to the scenario put forward in the EWB Challenge; this was an opportunity to evaluate the characteristics of those who had gone a step beyond just attending a module. The researcher anticipated that this sample group may present biased perspectives that were taken into account during the analysis and discussion. Attending the Challenge final event was a free choice by the students, once selected by the tutor at each university. In EWB's own words:

"Each year, the EWB Challenge design brief is based on a set of sustainable development projects identified by EWB with its community-based partner organisations. In past years, the EWB Challenge has included developing innovative and sustainable project ideas and solutions to support communities in Vietnam, India, Cambodia and rural Australia" (EWB-UK :2014).

The Challenge final event required students to provide a full presentation to experts in the field and respond to potential feedback. The following key observations were noted and compared to the observations matrix found in Table 3.1.

- Positive attitude within groups and other Engineers Without Borders' participants were observed using optimistic language towards making a change within the scenario being presented ***(Internal Locus of Control)***
- Open mindset towards developing multiple ideas within the activity parameters in conjunction with members of other groups ***(Creativity)***
- Creative problem-solving that developed multiple designs from the single original design brief. ***(Creativity)***
- High level of engagement and passion for the humanitarian cause and using knowledge to make a difference.
- Despite not winning, groups were gracious in defeat and shared continued support for other group members. ***(Perseverance & Tolerance to Ambiguity)***

4.2. Focus Group

These results come from a focus group where participants attending the EWB-UK Conference at University College London (UCL). Participants were asked to discuss two key terms, Humanitarian Engineering and Entrepreneurship. The two terms both interlink respectively with research question one and two. As with other results in this chapter, focus groups were designed in-line with methodological research approach discussed in Chapter 3. The key terms for the perception of participants of humanitarian engineering included:

- Altruism
- Appropriate Technology
- Global
- Holistic
- Interdisciplinary
- Poverty Relief
- Social Development
- Sustainable Development.

Thereafter entrepreneurship was discussed from the position of the engineer, which came up with the following points. The results gained from this method that associated with the extant entrepreneurship literature discussed in section 2.3 have been presented in bold.

- Opportunity capitalising behaviour

- Not just money
- Problem Solving
- Perception
- Can-Do attitude (Internal Locus of Control)
- Characteristics
- Systematic.

4.3. Stakeholder Interviews

All of these stakeholder interviews were conducted in conjunction with EWB-UK in order to evaluate how the challenge package was being developed and implemented in HE institutes across the UK. To fully understand the situations where these entrepreneurial characteristics have been identified, the following case studies were found to demonstrate the way in which humanitarian engineering is integrating into engineering education across the UK, and identify entrepreneurial characteristics observed by the staff running the EWB-UK Challenge.

4.3.1. Stakeholder Interview 1

This institution has the highest number of students engaged in the EWB Challenge as it delivered as a week-long mandatory activity for all engineering students. The challenge engaged students from all undergraduate engineering disciplines in a week-long intensive project. During this week-long process, students were brought together as one large group for large lecture-style sessions, but they were also broken into smaller satellite rooms headed up by PhD students in order to formulate their solutions and present them to the other students. Throughout this week-long session students were not formerly assessed, although they were engaged in live peer reviewing through the use of wireless clickers, therefore giving groups the ability to gain instant feedback on the solutions they had put forward and the way in which it was presented to the group.

Despite the all-inclusive nature of this approach to the EWB Challenge, it was not without its problems. One of the key issues faced in this instance was the slow nature of responses from the EWB volunteers in the field. Due to the intensive nature of the week, responses could not come quickly enough, therefore not giving quite a live view of the community as other institutions that implemented the challenge across a longer period of time. Despite this, students were still able to view previously asked questions from other students, which for the most part gave them the information that was required.

When questioned on enterprise within the EWB Challenge it was stated:

[It is] not exactly small-business if you know what I mean, it's just ***solving problems*** *basically. I suppose I would say that a lot of the time anything that's enterprise is often got a real-world solving-problems application to it. So anything...if I'm teaching, anything that a real-world, solving –industry-type problem then I would say it's got an enterprise link. So when we involve industry or involve real-world – so one of the, um, I*

suppose, flagship modules that runs not from this department but from Mechanical Engineering is one where they actually, they do, they contact a partner - and for several years it's been sort of medical or disability groups who need a problem solving - and mechanical engineers come up with a solution and prepare a business plan to take that forward as well.

These findings will be discussed further within the discussion chapter in reference to Creativity.

4.3.2. Stakeholder Interview 2

Following an EWB promotional presentation on the EWB Challenge, [the institution] signed up to integrate the challenge into the university's engineering programme. As with other case studies, the challenge was seen as a route out of standardised design projects, and a method of forcing students to consider scenarios outside their comfort zone. By integrating a selection of pedagogical practices and assessment criteria such as teamwork, written assignments and presentations, the challenge was recognised to have an improved student development level, compared to other modules. In terms of benefits noted from the use of the challenge to teach design, it was observed that when compared to other modules, the students appeared to have a longer lasting enthusiasm for the activities and overall outline of the module. [The interviewee] highlighted the importance of teamwork as a key selling point of the challenge as in industrial scenarios it is rare for graduates to be working alone, therefore getting them used to this working environment early was considered essential. The nature of the challenge brief gave students a real-world experience in their ability to make contact with external stakeholders and assess the situation involving resources, labour, costs, etc; which stepped away from other scenarios in the past that had been considered to be “boring” by students. As with all university’s monitoring of success and engagement it is difficult to get a full picture, however, from quantitative data gathering the challenge appeared to have a positive impact:

> *You’re never going to get 150 students 100% committed to anything, but simply based upon the attendance at tutorial sessions, workshops, and everything else, they were more alive, they were talking to each other, they were talking to me, I had a better relationship with students, everybody enjoyed it, it was a win-win situation.*

Despite these benefits, inevitably there were issues that arose due to the unique nature in which [the institution] integrated the challenge. The key problem came from the face-to-face time with staff members and the limited period of time students had to work through the challenge issues in regimented sessions rather than self-managing their time.

When entrepreneurship in engineering was discussed, [the interviewee] responded:

The enterprising engineer, the easy answer to that is the engineer who's got an entrepreneurial streak to him, but I don't think that's the only way to approach that. You have, you have engineers who are enterprising, I would say, are those who can see the ***opportunities*** *and grasp them and go for it, rather than treading the comfortable, well-trodden path, to think outside the box and to take the applications just that little bit further. I don't think it necessarily has to be tied into business, although it can be, I think that anybody who's enterprising in the broader sense of the word, has the ability to take what they know, what they understand, and what they've learned, and applied it in as wide a field as possible.*

These comments will be further examined within the discussion chapter in order to further support the existence of Opportunity Recognition within students studying humanitarian engineering.

4.3.3. Stakeholder Interview 3

Appropriate engineering is a core output from the use of the EWB Challenge, which is why the interviewee from the university saw it as being a good fit for their engineering department. The challenge was integrated into a second year professional skills module, giving a selection of engineering disciplines including mechanical and design, therefore improving their ability to use their knowledge base in contribution to other students' knowledge. The module outcomes required students to consider issues such as ethics, appropriate technology and cultural issues.

From the initial challenge brief the interviewee put a lot of work in prior to the module to expand the requirements, in order to give students a more structured path towards understanding these key issues. This extension of the original challenge brief was seen as a significant inhibitor of the university's use of the challenge, however, other than this, students appeared to appreciate and integrate with the challenge objectives relatively simply.

When asked about enterprising engineering, the interviewee stated:

> *I guess if someone said that to me I would think coming up with **innovative ideas**, but not necessarily from the perspective of helping an impoverished community.*

4.3.4. Stakeholder Interview 4

This institution delivered the EWB Challenge from a different approach that most of its counterparts, with more focus being put upon the professional skills and ethics elements of engineering and managing people rather than simply dropping in a ready-made solution that may not be appropriate for the end user. The module utilised the EWB Challenge as a cornerstone to apply a number of key concepts that in previous years had been taught for the sake of it rather than giving meaning a purpose to it.

It was noted in the interview that the use of the EWB Challenge within this module enhanced the students' learning, taking it "from a flat [subject] to a 3D subject". It was also noted that when compared to previous years of the same module, the level of enthusiasm for the task was increased.

> *It's part of a lecture that I give, that in order to take a new product to market you need three types of people: you need the ideas person – usually not an engineer, just comes up with good ideas. Then you need the engineer, who can tell you whether the product, you can actually make it, and what particular cost. And then you need the runner, who is the person who takes the idea, drives it forward, knocks on every door, goes the bank, gets the funding. Or you know, sources a factory to produce the goods. So those three types of person. And very rarely are all three found in one person. Ideally, they can be; you have James Dyson who obviously an **idea's person**, obviously he's an engineer, and he's also this person who can run with the idea. Even when Culvert turned him down, he pushed it through and made it happen. All three in one. That's why he's a very rich man. But very rare. Usually you have one, if you're lucky you've got two of the skills. But it can by extent, I think we are finding that you need to be more than just a one-trick pony. So yes, engineers who are entrepreneurial, engineers who are **creative**, engineers who are cultural – all of these things are, you know, perhaps the way forward".*

4.3.5. Stakeholder Interview 5

This institution integrated the EWB Challenge within a third year Material Science and Design Module, which also formed a part of the student's final year dissertation. The students engaged within this module came from a range of engineering-based disciplines and totaled approximately 75 individuals per academic year. This module had a degree of flexibility which illustrates a mixed approach when compared to other approaches discussed within these interviews, as mechanical engineering students were required to take the class, whilst students from other engineering degrees had the option of participating in the module.

This institution had experimented with other humanitarian and international projects previous to integrating the EWB Challenge, with varying degrees of success. One of the key values associated with the Challenge that attracted the university into it was the ethical dimension of engineering and making students understand the human element of any engineering project. Another key reason for the implementation of the challenge was its ability to focus students on the internationalisation aspect of engineering, as this is a key part of the university's overall goal and as a part of aligning with the Engineering Councils' chartered status competency guidelines.

Following completion of the first year of the Challenge, it was noted that in future years the challenge should be percolated down into the earlier stages of the degree programme into a more generalised module, giving many more students the opportunity to take part and absorb the key lessons. When discussing the value of enterprise within engineering education the participant suggested that:

> *It is encouraged, but tacitly; you could consider your undergraduate degree as giving you the skills to be an entrepreneur if you wanted to be, we have plenty of students that have gone out and gone down that route, but it doesn't suit everybody. So yes absolutely I do, working at a research intensive university so a lot of our work is research rather than teaching, so on the research side absolutely, it's about making value out of the things you're doing and research projects are ever more geared in having impact in terms of sales; although that may be a bit glib; coming up with something that has an impact in the future and that impact is only monetary, rather than anything else. It can be societal, but for it to be societal, you need to sell it to them; which works out to be the same thing.*

4.3.6. Stakeholder Interview 6

The integration of the Challenge at this university took place within a product design engineering degree. Although a number of benefits were observed from using the challenge at this institution, time appeared to be a key limiting factor in the success of the initial application of the Challenge. The Challenge was integrated into a second-year mechanical systems, which was a strategic choice in order to engage the group of students within the degree course that prefer the design element rather than the technical, which is where the Challenge was able to bridge the gap.

Although the 20 students engaged within this module did appear to demonstrate enjoyment of the learning pedagogy, there were issues with the students' integration with the external knowledge and resources provided by EWB in order to inform the students thinking and decisions. This module was dominated by a 100 per cent male attendance, which was not the norm when compared to previous years of 15:85 (female: male) split, however it was the motivation of using the EWB Challenge to further engage female engineers due to the anecdotal evidence seen in engagement with other similar scenarios.

In terms of entrepreneurship playing a part in the integration of the challenge at this university, it was suggested that being entrepreneurial was an essential part to the students' development through their degrees, however the use of the word entrepreneurial was often related to business scenarios, which the interviewee disagreed with in principle. Instead it was highlighted that entrepreneurship is a matter of perception of the students and how they view situations, which in terms of engineering is essential to creating solutions that respond actively to the needs of all stakeholders.

4.3.7. Stakeholder Interview 7

This institution works towards including humanitarian engineering into its engineering curriculum, in order to engage students in the arena of international development. The structure utilised within this institution was a second-year module entitled Civil

Engineering Design, which focused primarily on students primarily studying civil engineering-based modules. Students were required as a part of the assessment for this module to undertake a building design task whilst taking into consideration the numerous non-engineering issues, such as resources, culture, social structure, religious perspectives, etc. As a part of running the challenge within this module, students were provided with guest speakers from differing disciplines to provide a multi-disciplinary approach to the task at hand. Following the task and guest lectures, students were assessed through the use of poster presentations to two members of staff.

Despite the underlying positive regarding the EWB Challenge following feedback from students it was found there was a lack of apathy by many, in the support of the community case studies. Another issue faced was the inability to use the live community forum, therefore restricting the amount of real-time information they were able to gather and apply to their design; however, this issue was temporary; it went to demonstrate how the impact a lack of knowledge could restrict progress.

The interviewee was surprised by the use of the term enterprising engineer, but when pushed described it as:

> *It's an engineer that sees the need and looks for the need and then attempts to fill it. Had you asked what entrepreneurial engineer was, I would have been very much in the business area.*

4.3.8. Stakeholder Interview 8

Unlike the other institutions discussed that delivered the EWB Challenge as a class within a suite of elective modules (although there are other humanitarian-based case studies being introduced across other mandatory modules such as design) this series of elective modules has been developed in order to allow students the opportunity to study a subject area not necessarily directly linked to their degree course, from languages to photography. As well as offering the students a greater choice in their education, the modules all have a specific focus upon student's personal development and employability skills to assist in career management post-graduation.

Students are introduced to the EWB Challenge through a first-year module, entitled The Global Engineer – Engineers Without Borders Challenge. Delivered by the interviewee, a senior lecturer in Civil Engineering, the module is delivered over a ten-week process and follows the Challenge specifics delivered from EWB. The assessment method allows students to develop a piece of work that both serves the basis of the module criteria but also allow students to enter the Challenge competition which is held each year. Since the EWB Challenge was established, the students from this university have achieved first and second places.

4.4. Questionnaires

The entrepreneurial characteristic questionnaire is a core element of this research, giving the ability to gain statistical data and determine significance across each of the characteristics highlighted within the Literature Review (Chapter 2) and Research Methodology (Chapter 3) chapters. All of the tables and figures found in this section were created using the software package SPSS; details of which can be found in the Research Methodology chapter. The initial sections have been used to demonstrate the validity and reliability of the questionnaire. This is then be followed by a breakdown of the 11 entrepreneurial characteristics and the Mann-Whitney tests to determine significant differences between the three sample groups, Humanitarian Engineering, General Engineering and Enterprise students.

The table below provides an insight into the number of participants and how they are split across the three key sample groups.

Sample Frequencies

	Frequency	Per cent
Humanitarian	199	25.8
Engineering (Control)	305	39.6
Enterprise	266	34.5
Total	770	100.0

Table 4.2 Questionnaire response figures

The following sections are broken down to first examine the validity of the research tool and whether it able to discern the differences between participants who are, and those who are not, entrepreneurially minded.

4.4.1. Questionnaire Reliability and Validity Testing

On the outset of this these results it is important to state the level of internal reliability that is provided by 33 Likert scale questions. To enable this, a Cronbach Alpha reliability test was conducted and the result was .651. As discussed within the Methodology Chapter (see section 3.5.3 on page 78) a Cronbach Alpha level, higher than 0.6 is considered an acceptable level to consider the results of the questionnaire to be internally reliable, at this stage of research development (Nunnally *et al.* 1967). To further analyse the reliability, the table below has been generated to demonstrate how the Cronbach Alpha would change when each of the questions are omitted from the results data.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q1	91.00	48.821	.108	.650
Q2	91.81	49.055	.021	.659
Q3	91.89	49.699	-.039	.664
Q4	91.56	47.824	.139	.648
Q5	90.99	46.410	.360	.632
Q6	91.28	47.571	.184	.645
Q7	91.17	48.174	.187	.645
Q8	90.83	46.407	.412	.631
Q9	90.72	46.890	.363	.634
Q10	90.94	47.417	.266	.640
Q11	91.03	46.890	.324	.636
Q12	91.02	48.373	.174	.646
Q13	91.33	45.902	.269	.637
Q14	90.98	47.219	.206	.643
Q15	91.18	47.275	.193	.644
Q16	91.30	45.740	.287	.635
Q17	91.74	46.507	.231	.640
Q18	90.89	46.776	.323	.635
Q19	90.87	48.083	.199	.644
Q20	91.07	46.142	.258	.638
Q21	91.58	45.323	.334	.630
Q22	91.35	44.877	.350	.628
Q23	91.68	48.587	.052	.657
Q24	91.56	46.792	.221	.641
Q25	91.36	45.969	.281	.636
Q26	92.39	52.116	-.265	.678
Q27	91.45	45.647	.290	.634
Q28	**91.70**	**52.029**	**-.247**	**.679**
Q29	91.08	48.362	.111	.650
Q30	91.51	48.373	.056	.658
Q31	90.99	46.684	.238	.640
Q32	91.39	47.183	.194	.644
Q33	90.78	46.190	.310	.634

Table 4.3 Cronbach Alpha analysis with each question removed

Table 4.3 indicates that the overall spread of Cronbach Alpha results are closely clustered together, therefore suggesting none of the 33 questions are skewing the overall data set. However, to further increase the Cronbach Alpha level for the overall questionnaire the most appropriate question to be removed would be Question 28, however this would potentially lead to bias in other questions, therefore requiring a detailed analysis prior to developing the questionnaire further.

4.4.2. Pilot Testing

As discussed within the Literature Review there is an ongoing discussion as to whether being entrepreneurial requires an association with the establishment of a new business venture. Whilst it is stated that running or starting a business is not a necessary for entrepreneurship, the 11 characteristics do act as a precursor to business start-up. As a method of pilot testing of this research methodology, the 770 participants are asked whether they had ever run a business. From the total number of participants 18.1 per cent responded to state they had previously run their own business. The graph below highlights a culmination of the 11 characteristics and validates the ability of the methodology to identify business ownership from the adapted Gasse and Tremblay's Entrepreneurial Characteristic Inventory (2006).

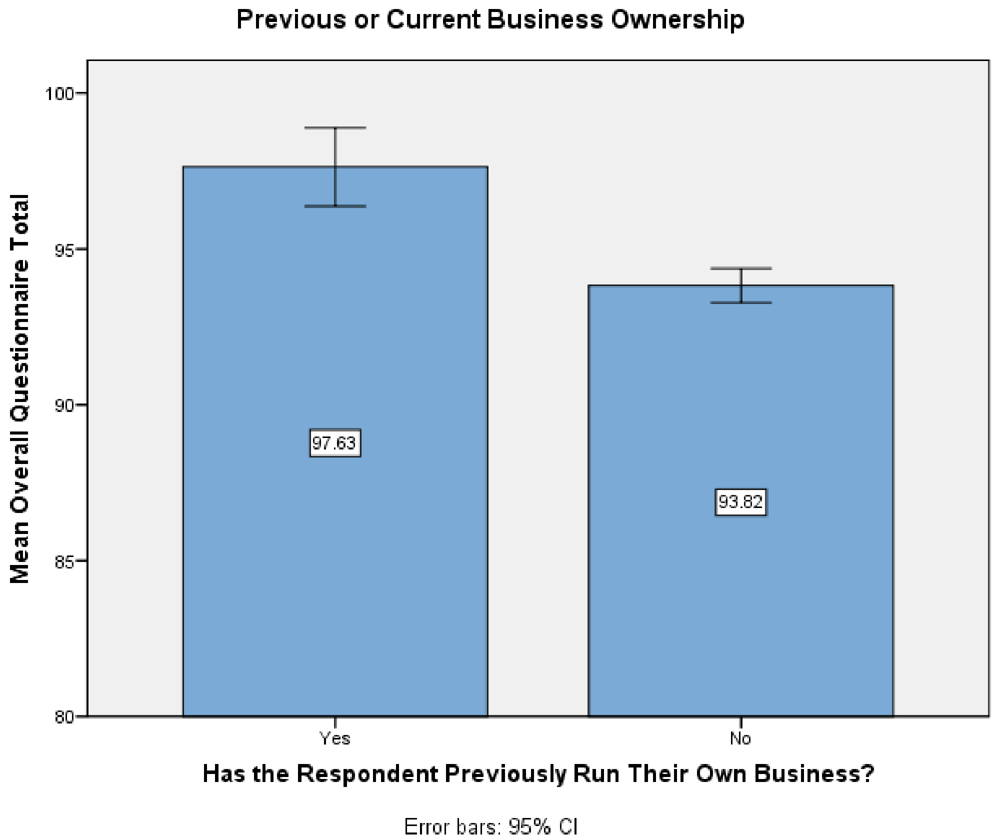

Figure 4.1 Total scores compared with those with and without business experience

As the graph demonstrates, when taking into account the error margin, it is stated that those who had previously or currently run businesses showed an increased cumulative characteristic result. These results reaffirm Gasse and Tremblay's original design of the questionnaire towards measuring entrepreneurial characteristics as the traits required for business.

Rather than simply seeing a difference in mean values defined by the table above, it is essential to use statistical analysis processes to gain an understanding of what level of significance, if any can be found to respond to the hypothesis and ultimately answer the research question. The Independent Samples Test below analyses the difference between the cumulative questionnaire result from those that have and have not run their own businesses before.

	Levene's Test for Equality of Variances				
	F	Sig.	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	5.233	.022	.000	3.805	.634
Equal variances not assumed			.000	3.805	.697

Table 4.4 Statistical significance analysis of previous business experience results

Table 4.4 demonstrates the statistical significance between the mean scores achieved by those who have and have not previously run businesses. In this Independent Samples Test the significance score is 0.000, which is considerably less the >0.05 target used as a standard in statistical analyses of this sort.

4.4.3. Individual Characteristic Analysis Summary

Following the collection and statistical analysis of the quantitative data, Figure 4.2 has been created to effectively demonstrate the differences in values between samples in each characteristic category. Each of the characteristics was measured on a 12 points scale, with the mean difference between the sample respondents being less two points. These two points are shown in the radar graphic below.

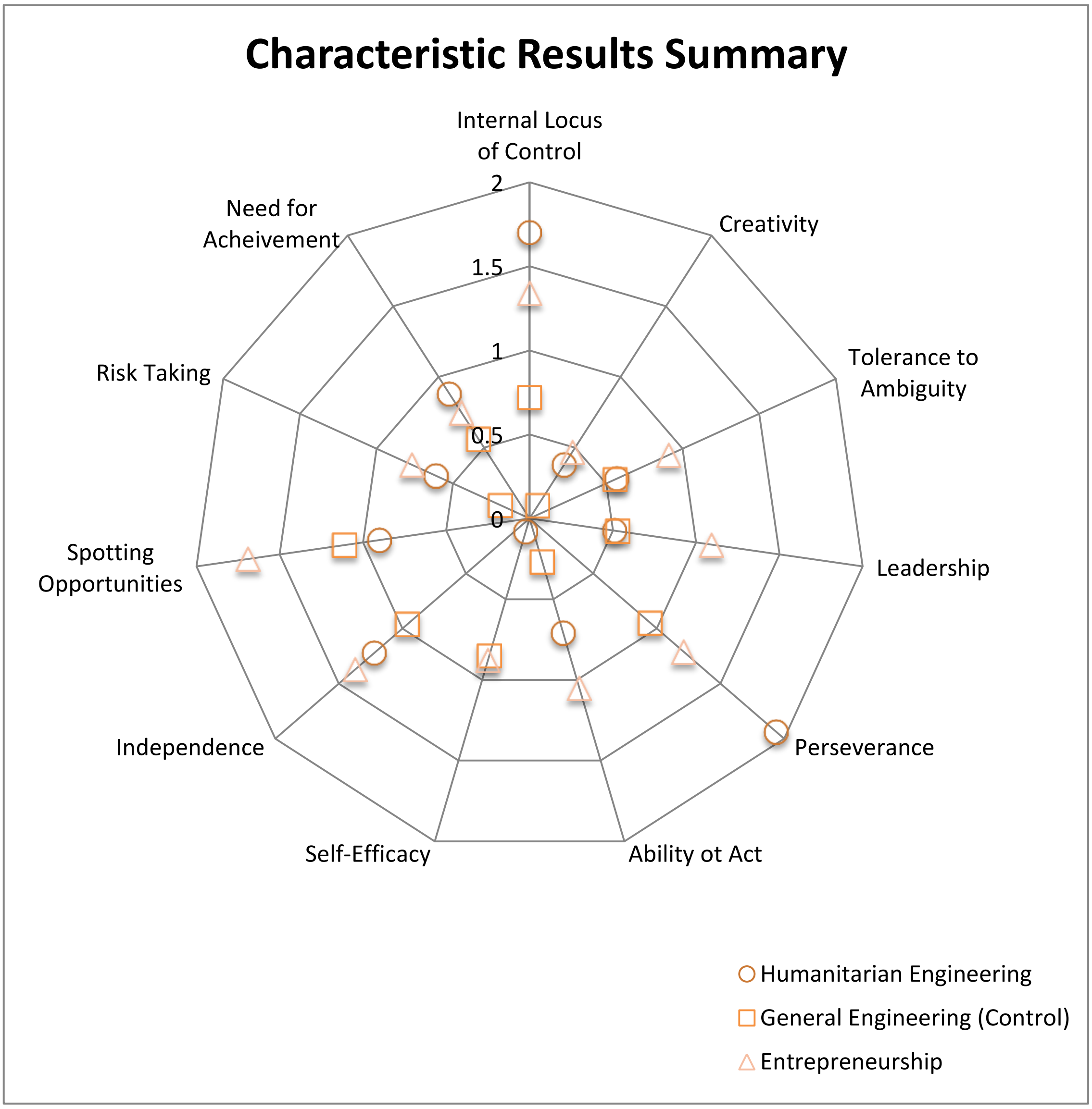

Figure 4.2 Characteristic Results Summary

Following the plotting of the results shown within Figure 4.2, a series of Mann-Whitney U Tests were conducted to analyse the P-value relation between each sample group. Each of the graphical representations of these analyses are presented within Appendix 5.

To summarise the Mann-Whitney U Tests shown above, the table below highlights the overall significance value for each characteristic total when compared between Humanitarian Engineering students and Non-humanitarian Engineering Students, as well as clearly stating whether the null hypothesis should be accepted or rejected. Within the table below, the orange highlighting denotes Humanitarian Engineering students being significantly higher than the general engineering control group.

Humanitarian Engineering Vs General Engineering (control) Hypothesis Test Summary				
Characteristic	**Test**	**Sig.**	**Decision**	**Is Humanitarian > General Engineering?**
Action Orientation	Mann-Whitney U Test	.001	Reject the null hypothesis.	**Yes**
Creativity	Mann-Whitney U Test	.005	Reject the null hypothesis	**Yes**
Independence	Mann-Whitney U Test	.027	Reject the null hypothesis.	**Yes**
Internal Locus of Control	Mann-Whitney U Test	.000	Reject the null hypothesis.	**Yes**
Leadership	Mann-Whitney U Test	.980	Retain the null hypothesis.	No
Need for Achievement	Mann-Whitney U Test	.032	Reject the null hypothesis.	**Yes**
Opportunity Recognition	Mann-Whitney U Test	.088	Retain the null hypothesis.	No
Perseverance	Mann-Whitney U Test	.000	Reject the null hypothesis.	**Yes**
Risk Taking	Mann-Whitney U Test	.000	Reject the null hypothesis.	**Yes**
Self-Efficacy	Mann-Whitney U Test	.000	Reject the null hypothesis.	No
Tolerance to Ambiguity	Mann-Whitney U Test	.797	Retain the null hypothesis.	**Yes**
The significance level is < .05.				

Table 4.5 Mann-Whitney U Test between Humanitarian & Engineering Samples summary

Following the results summarised in Table 4.5 Mann-Whitney U Test between Humanitarian & Engineering Samples summary, the table below provides the collation of determined hypothesis relating to each of the 11 characteristics.

Action Orientation	*Action orientation* is higher in students studying humanitarian engineering, compared to those studying other forms of engineering.
Creativity	*Creativity* is higher in students studying humanitarian engineering, compared to those studying other forms of engineering.
Independence	*Independence* is higher in students studying humanitarian engineering, compared to those studying other forms of engineering.
Internal Locus of Control	*Internal locus of control* is higher in students studying humanitarian engineering, compared to those studying other forms of engineering.
Leadership	*Leadership* is the same in students studying humanitarian engineering, compared to those studying other forms of engineering.
Need for Achievement	*Need for achievement* is higher in students studying humanitarian engineering, compared to those studying other forms of engineering.
Opportunity Recognition	*Opportunity recognition* is the same in students studying humanitarian engineering as those studying other forms of engineering.
Perseverance	*Perseverance* is higher in students studying humanitarian engineering, compared to those studying other forms of engineering.
Risk Taking Propensity	*Risk taking propensity* is higher in students studying humanitarian engineering, compared to those studying other forms of engineering.
Self-Efficacy	*Self-efficacy* is lower in students studying humanitarian engineering, compared to those studying other forms of engineering.
Tolerance to Ambiguity	*Tolerance to ambiguity* is the same in students studying humanitarian engineering, compared to those studying other forms of engineering.

Table 4.6 Hypotheses statement results

To further understand the differences between Humanitarian Engineering students and other students, the following two tables have been generated to firstly show the significance factor between Humanitarian Engineering students and Enterprise students; and the second to look at the significance between Non-Humanitarian

Engineering students and Enterprise students. Within the table below, the orange highlighting denotes Humanitarian Engineering students being significantly higher than Enterprise students.

Humanitarian Engineering Vs Enterprise Students Hypothesis Test Summary				
Null Hypothesis	**Test**	**Sig.**	**Decision**	**Is Humanitarian > Enterprise?**
Action Orientation	Mann-Whitney U Test	.013	Reject the null hypothesis.	No
Creativity	Mann-Whitney U Test	.708	Retain the null hypothesis.	No
Independence	Mann-Whitney U Test	.273	Retain the null hypothesis.	No
Internal Locus of Control	Mann-Whitney U Test	.001	Reject the null hypothesis.	**Yes**
Leadership	Mann-Whitney U Test	.000	Reject the null hypothesis.	No
Need for Achievement	Mann-Whitney U Test	.516	Retain the null hypothesis.	**Yes**
Opportunity Recognition	Mann-Whitney U Test	.000	Reject the null hypothesis.	No
Perseverance	Mann-Whitney U Test	.000	Reject the null hypothesis.	**Yes**
Risk Taking Propensity	Mann-Whitney U Test	.297	Retain the null hypothesis.	No
Self-Efficacy	Mann-Whitney U Test	.000	Reject the null hypothesis.	No
Tolerance to Ambiguity	Mann-Whitney U Test	.007	Reject the null hypothesis.	No
The significance level is < .05.				

Table 4.7 Mann-Whitney U Test between Humanitarian & Enterprise Samples summary

Table 4.7 demonstrates the results comparison between the general engineering student control group and the enterprise students. Unlike the Humanitarian

Engineering students highlighted in Table 4.7, the general engineering students had no higher levels of characteristic than the enterprise group. Although the characteristics self-efficacy and need for achievement, were not significant, the two groups were in close proximity with their mean results.

Engineering Students Vs Enterprise Students Hypothesis Test Summary				
Null Hypothesis	**Test**	**Sig.**	**Decision**	**Is Engineering > Enterprise?**
Action Orientation	Mann-Whitney U Test	.000	Reject the null hypothesis.	No
Creativity	Mann-Whitney U Test	.002	Reject the null hypothesis.	No
Independence	Mann-Whitney U Test	.000	Reject the null hypothesis.	No
Internal Locus of Control	Mann-Whitney U Test	.000	Reject the null hypothesis.	No
Leadership	Mann-Whitney U Test	.000	Reject the null hypothesis.	No
Need for Achievement	Mann-Whitney U Test	.126	Retain the null hypothesis.	No
Opportunity Recognition	Mann-Whitney U Test	.000	Reject the null hypothesis.	No
Perseverance	Mann-Whitney U Test	.004	Reject the null hypothesis.	No
Risk Taking Propensity	Mann-Whitney U Test	.000	Reject the null hypothesis.	No
Self-Efficacy	Mann-Whitney U Test	.691	Retain the null hypothesis.	No
Tolerance to Ambiguity	Mann-Whitney U Test	.002	Reject the null hypothesis.	No
The significance level is < .05.				

Table 4.8 Mann-Whitney U Test between Engineering & Enterprise Samples summary

4.5. Interviews

The interviews conducted with HE institutions that are delivering the EWB-UK Challenge have been utilised to introduce seven stakeholder interview case studies (see section 4.3). This interview data and that conducted with individuals engaged in humanitarian engineering activities in HE and globally are further developed and presented within the discussion chapter, in reference to each of the key characteristics to provide contextual meaning to the statistical data. For full transcripts of the anonymised interviews, please see the CD ROM enclosed in Appendix 4.

A synthesis of the interview data that is directly related to the debate of what humanitarian engineering means is displayed below within Figure 4.3 as a mind map.

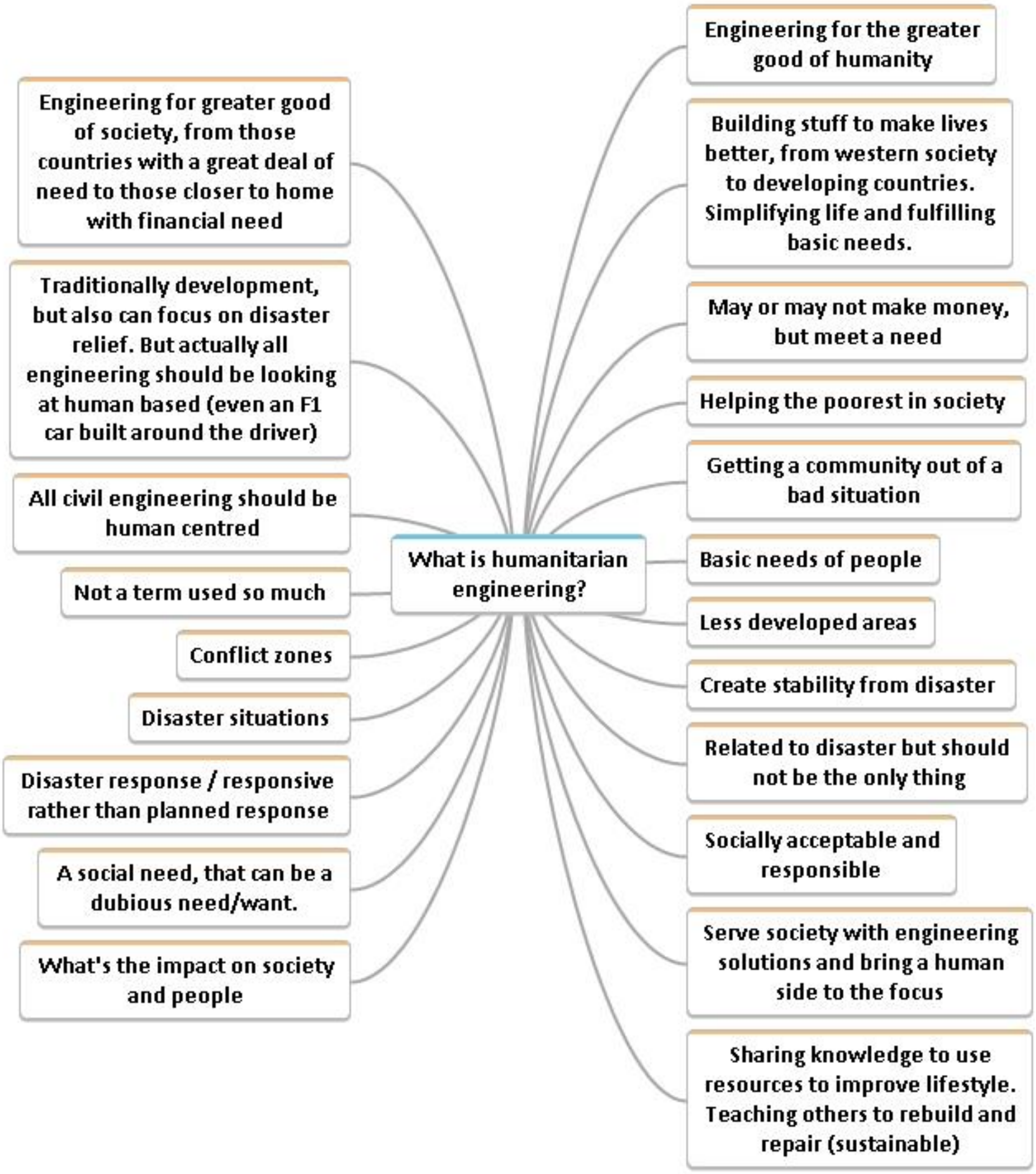

Figure 4.3 Interview data summary on 'what is humanitarian engineering?'

To summarise the links between engineering and the enterprise characteristics discussed within the interviews, a series of mind maps have been created for each characteristic below (Buzan 2002). Each mind map's contents were derived through the coding of the interview data through the NVivo software package. The analysis was initially carried out utilising a keyword approach, and was further refined through detailed analysis of the initial keyword results (for further detail see section 3.6.2). These results are discussed throughout chapter 5.

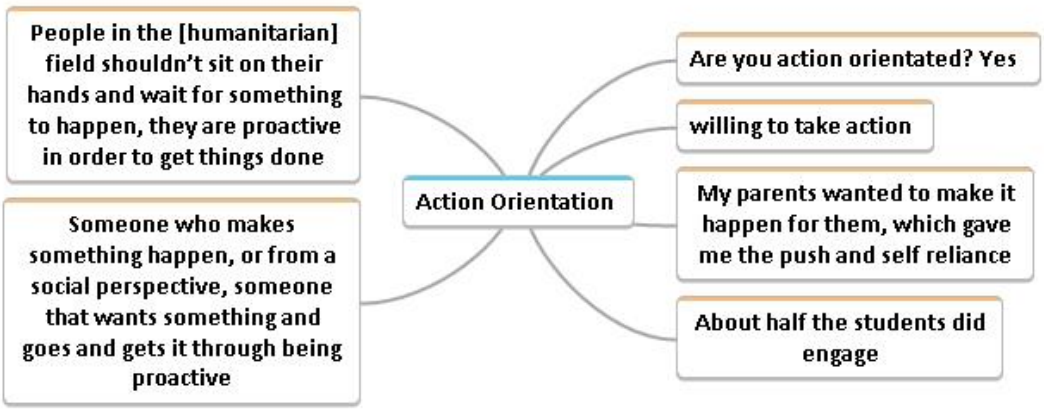

Figure 4.4 Interview data summary associated with action orientation

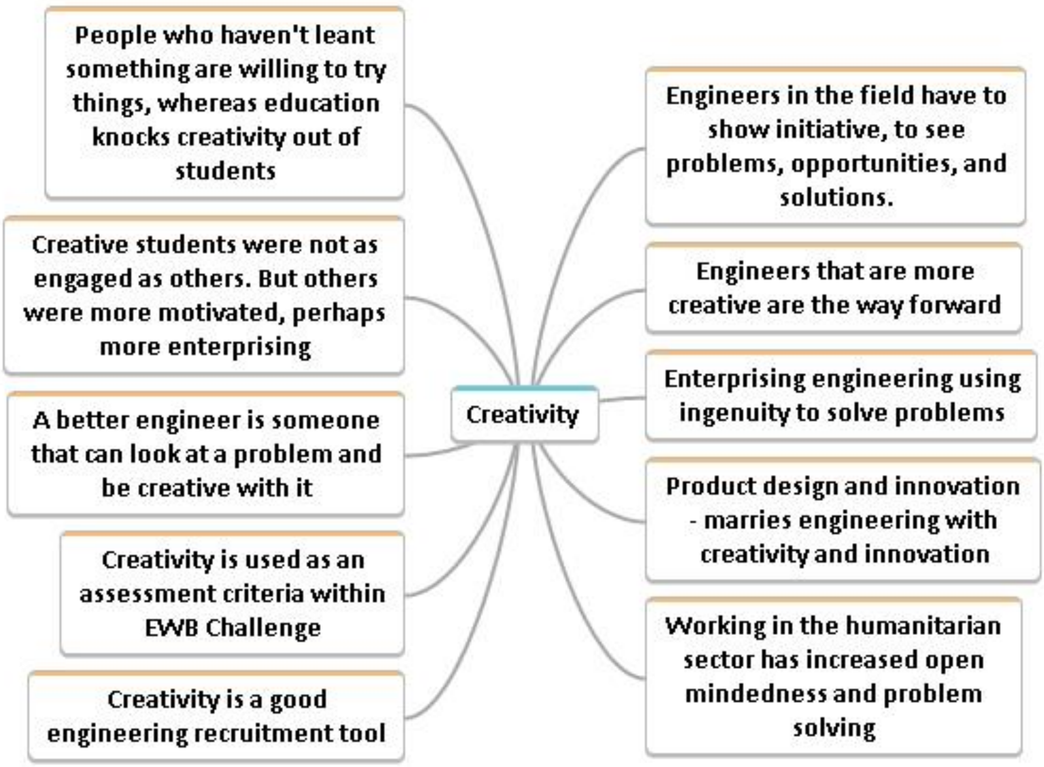

Figure 4.5 Interview data summary associated with creativity

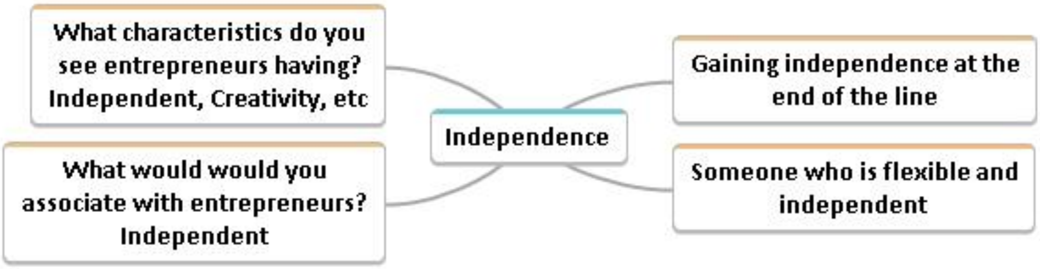

Figure 4.6 Interview data summary associated with independence

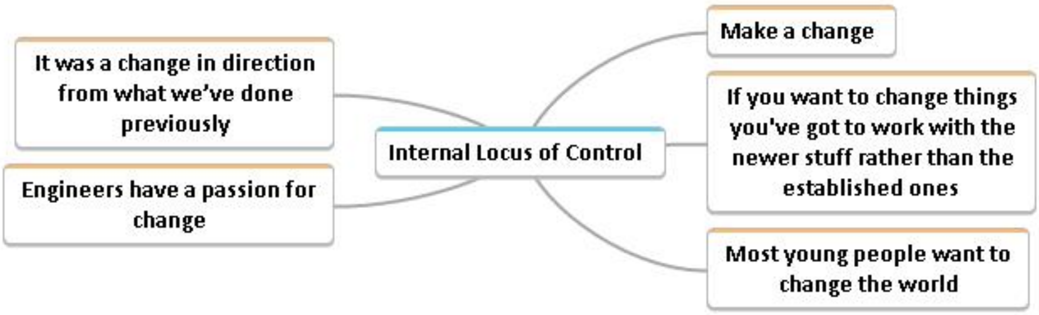

Figure 4.7 Interview data summary associated with internal locus of control

Figure 4.8 Interview data summary associated with leadership

Figure 4.9 Interview data summary associated with need for achievement

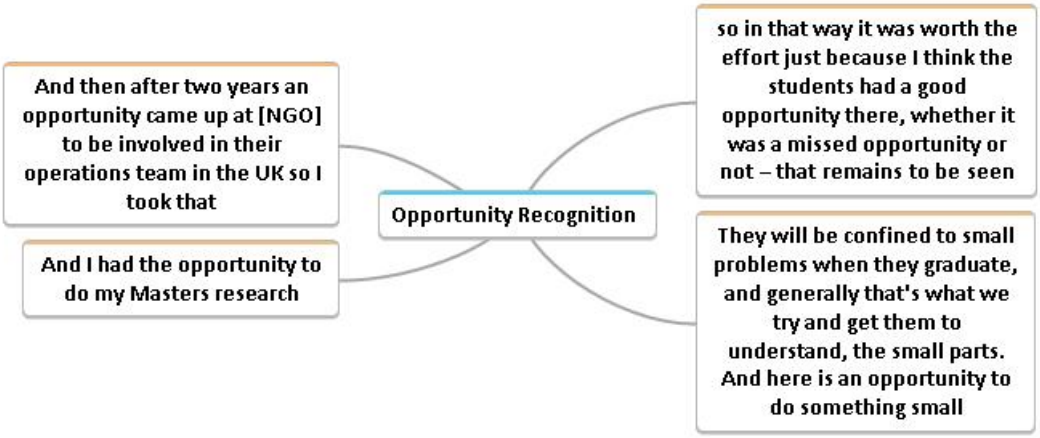

Figure 4.10 Interview data summary associated with opportunity recognition

Figure 4.11 Interview data summary associated with perseverance

Figure 4.12 Interview data summary associated with risk-taking propensity

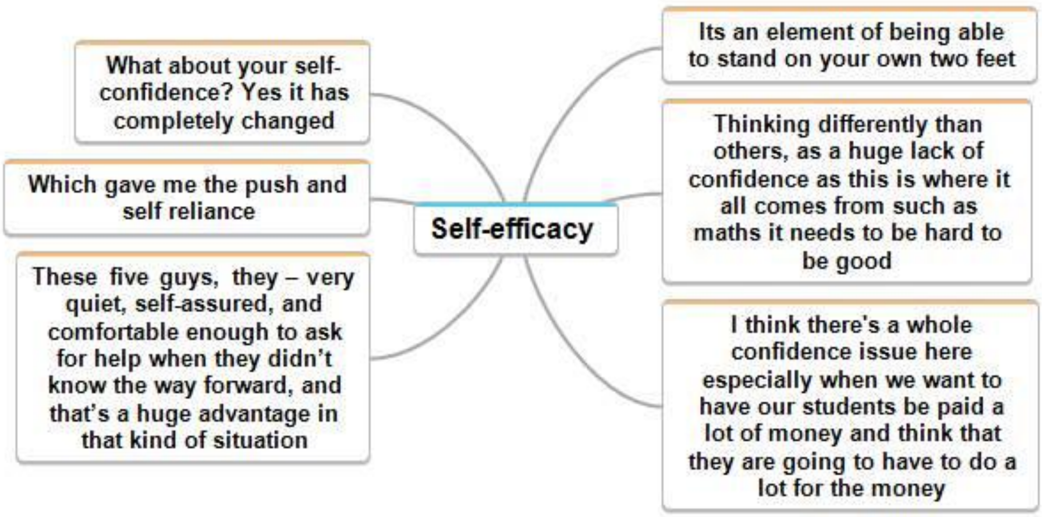

Figure 4.13 Interview data summary associated with self-efficacy

Figure 4.14 Interview data summary associated with tolerance to ambiguity

4.6. Summary

Leading from the four research methods discussed within chapter 3, this chapter has provided the key findings within the observations, interviews, focus groups and questionnaire data. This data is now unpacked and discussed in further detail to respond to the research questions and elaborate upon the contribution this study is making to the Humanitarian Engineering and Entrepreneurship disciplines.

5. Discussion

This chapter sets out the main arguments that respond to the research questions:

1. *How is the term humanitarian engineering understood by UK academics delivering the EWB-UK Challenge?*
2. *Critically assess to what extent do humanitarian engineering undergraduate students possess entrepreneurial characteristics?*

The discussion looks at the findings within the current body of literature and establishes a new contribution to this knowledge base. The following sections take into consideration the quantitative and qualitative data collected, to formulate a conceptual framework that demonstrates responses to the research questions. Sections 5.1 and 5.2 focus upon humanitarian engineering specifically, whilst sections 5.3 onwards present the discussion around the entrepreneurial characteristics that are revealed to be significantly higher in the humanitarian engineering sample group than the general engineering control group. The summary of this section presents the broader impacts of this research.

5.1. What is Humanitarian Engineering?

Given the acceleration of the use of the term humanitarian engineering in both the field and in HE, this study sought to develop further understanding of the term. This is accomplished through the discussion of results gathered through a focus group and interviews with those that study it and those that teach it. Whilst Vandersteen *et al.* (2010), Ong (2015) and others have presented their interpretation of humanitarian engineering from varying perspectives, the view from a UK HE perspective has yet to be contributed to the overall body of knowledge.

Within the focus group, a number of keywords were drawn out through questioning that proposed a picture of what humanitarian means within a UK HE aspect. The first point to recognise from the focus group data is the lack of any geographic focus within the responses, other than the proposal of the word 'global'. This suggests that these individuals perceive their roles as humanitarian engineers, as assisting communities wherever they may located. This contradicts a proportion of the extant literature that highlights the focus on humanitarian engineering as being primarily in disaster zones (Reed 2002) or developing countries (Ferrer-Balas *et al.* 2005), whilst aligning with Vandersteen's (2009) perspective of humanitarian engineering being applicable to local, national and international communities that are in need. On review of the EWB-UK website itself, there is a primary focus upon international support. Regarding the remaining keywords highlighted by the focus group, none of these directly refer to the geographic location of the solution beneficiaries. The highlighting of poverty relief as another core strand of humanitarian engineering indicates a potential for confusion towards the term, as the level of poverty globally is recognised as having hot spots within developing countries, yet some levels of poverty can also be viewed within western societies.

Whilst the engineering knowledge is highlighted as being important, both within the previous literature and the focus group findings, six of the eight keywords suggested by the group, do not link to engineering directly. Terms such as altruism and holistic, suggests that these individuals hold a mindset that would see them helping others, whether or not they were engineers (student or professional). The other terms, social development and sustainable development, are also applicable to more than simply engineering activities. Hall *et al.* (2010) discuss the ability for entrepreneurship to be a tool towards sustainable development, therefore suggesting further synergy between the humanitarian engineering movement and entrepreneurship, both in the individuals that they attract and the opportunities that can be created through their effective merging. As well as the broad opportunities available to multiple disciplines, there is also a strong engineering position for sustainable development within engineering, as there is a greater need now to ensure long-term sustainable projects, as physical and human resources become increasingly limited (Royal Academy of Engineering 2006).

The terms discussed within the focus group that do directly associate with the engineering discipline, ‘appropriate technology’ and ‘interdisciplinary’ are noted as being broad in nature. Certainly within the initial examples discussed by Ong (2015) appropriate technology specifically can be beneficial in locations and communities that have limited resources. However, the need for appropriate technology is appropriate for any engineering solution to individuals and communities that are disadvantaged in some way.

Whilst these findings provide insight into the mindset of those who consider themselves to be humanitarian engineers, all of those engaged with this focus group were actively engaged with EWB-UK, which may skew the discussion. Whilst this data may represent the views of only a segment of those engaged in humanitarian engineering activities, the segment engaged with EWB-UK and EWB globally, it is arguable the largest is within the global context. Therefore as the discussion continues through the other results collected, this potential for bias is considered.

Following the interviews with academics that are involved in delivering the EWB Challenge within their respective institutions, the discussion around humanitarian engineering, presented several findings. The first finding was the lack of recognition for the term ‘humanitarian engineering’. Many of these academics referred to not using the term often within their teaching, and instead using broader understandings such as sustainable and community engineering. A synthesis of the findings from these interviews can be found in figure 4.3 (see section 4.5).

Despite a lack of usage for the term humanitarian engineering, the academics interviewed highlighted a spectrum of meanings for humanitarian engineering. In the first instance, participants stated they saw the term primarily relating to immediate need for engineering support, in situations such as natural disasters and conflict. However, interviewees broadened the meaning, through discussion of communities within developing countries that have a need for basic commodities such as those considered normal for many, such as water, shelter and power. Beyond those that are in need of basic commodities in developing countries, the responses also broadened to encompass those in need within UK communities as well as further afield. These individuals who are disadvantaged by their circumstances, such as those that are disabled, were highlighted as being an opportunity for growth and integration within the humanitarian engineering field, as it is was highlighted that connecting the students with the beneficiaries can enhance the understanding of the problem, which can be easier when these are local. One of the interviews expressed a potential for emotional apathy to affect the connection with those in need that located in developing countries.

The other side of the spectrum presented is the thought that all engineering should be humanitarian centric. Whilst this view is understandable as engineering projects inevitably have impacts upon humans, the impetus for these developments may be focused upon the generation of profits, rather than the ultimate impact the solution has. An example of this might be the mobile telephone. This technology has had a substantial impact upon the global economy and has developed many technological advances (Howell *et al.* 2008; Lindsay *et al.* 2009). A by-product of this process has led to low-cost mobile phones spreading through global communities that has removed a degree of disadvantage that they had previously possessed (Kaplan 2006; Duncombe and Boateng 2009).

These perspectives reflect to an extent the definitions presented by Vandersteen *et al.* (2011) and Ong (2015), however the presence of the term humanitarian engineering within the UK is only in a small number of academic instances, such as at the University of Wales Trinity Saint David and Coventry University. The adoption of a shared terminology across the UK engineering education sector, could support the humanitarian movement within the student consciousness, as well as gain momentum within the political landscape to influence policy changes.

5.2. Entrepreneurial Characteristics

The following sections detail the key findings of this research in the specific enterprise characteristic themes. The discussion initially focuses upon the statistically significant findings and then goes on to discuss the implications where no difference was found between the sample groups. Sections 5.2.1 through to 5.2.7 discuss the characteristics that were found to be significantly higher than in the general engineering control group, whilst section 5.2.8 discusses the only characteristics found to be significantly higher in the general engineering control group.

5.2.1. Action Orientation

As with previously discussed entrepreneurial characteristics, action orientation measured within the humanitarian engineering and general engineering sample groups, is found to be significantly higher in humanitarian engineering students.

The group interview highlighted the association between taking action and being entrepreneurial, as one that exists from an outsider perspective, which further justifies its measurement within this study. The existence of action orientation within both the humanitarian engineering and professional engineer field is further supported by the responses within interview 7 and 12. However, this is not to suggest that all the students taking part in the humanitarian engineering-based activities were proactive. This was highlighted by one of the academic interviews that stated that around half of students within the mandatory module were engaging with the content. This factor demonstrates a need for future research to take the mandatory or optional modules into consideration, as this study's quantitative data is based upon an elective module. If conducted within a mandatory humanitarian engineering module, it is hypothesized that the results would be significantly different. A synthesis of the interview results can be found in figure 4.4 (see section 4.5).

Within the observations of those students studying humanitarian engineering, action orientation was identified within one of the groups. A distinct level of discussion was observed, as well as action and experimentation upon the task. The action being undertaken moved the group closer to the task completion, however due to the level of discussion and contradicting views, the results of the action were not as beneficial as others.

The proverbial saying 'knowledge is power' is appropriate to a certain extent, however given the focus upon action orientation, an updated version may be more accurate, 'knowledge that is actioned is power'. Sitting within an educational context humanitarian engineering is a concept that presents engineering scenarios that are different from the traditional ones. But how many of these individuals take action to have an impact? The participation within EWB-UK university chapters as an extra-curricular activity demonstrates this action orientation behaviour for example.

Within the literature review a connection is discussed between a proactive personality and job performance within the software engineering field (Rodrigues and Rebelo 2013). Therefore the findings of this research, stating that action orientation was significantly higher in the students studying humanitarian engineering, predicates that this impacts upon future job performance. This increase in job performance is likely to have economic impact by improving overall performance of an organisation. Given the connections discussed between entrepreneurship and action orientation, these results suggest that these humanitarian engineers have one of the key characteristics highlighted as being important to starting and/or running a business (Becherer and Maurer 1998; Lindgren and Packendorff 2003).

Although the word action is used in two of the UK-SPEC competencies, it is not the primary focus of the competencies. Nevertheless, the competencies relate to important factors of the engineering professional, and highlight the importance of not just identifying “variations from the quality standards, programme and budgets” (Engineering Council 2012:26) but also taking the corrective action to resolve the issue. These quantitative and qualitative results therefore indicate a greater advantage towards the humanitarian students in being able to achieve Chartered Engineer status. Whether in a humanitarian, entrepreneurial or general engineering context, the higher levels of action orientation within these students suggests an improved employability trajectory.

5.2.2. Creativity

As the results in section 4.4 highlight, the humanitarian engineering students displayed significantly higher levels of creativity than the general engineering control group. These results were echoed through the interviewing of those that had engaged with humanitarian engineering and the academics that had delivered the EWB Challenge. Interviewee 8 noted that being engaged within humanitarian engineering work, as well as work within their current engineering industry role, saw creativity play a key role within the characteristics they needed to utilise. Another industry interviewee (interview 10) stated that they felt their work within the humanitarian sector had increased their open mindedness and problem-solving, which is to be expected given the increased variety of factors that are required to be taken into consideration.

Unlike the observations of students that relate to action orientation, the existence of creativity was noted within the observation results within multiple groups. The development of multiple solutions, discussed verbally and followed by experimentation was observed in three groups as dominant characteristics. Rather than wasting the resources available to the teams, the creative discussion allowed for an appropriate strategy to be created and implemented.

From the academic interviews, creativity was found to be one of the most common key characteristics discussed, from the 11 researched within this study. From the initial implication of the EWB Challenge within a range of modules (see section 4.3), creativity was identified as a key factor for the Challenge's use. Creativity was highlighted as being *"the way forward"* within the development of successful graduate engineers (interview 6). This is further reaffirmed when a respondent noted that ingenuity is the stem of all engineering practice. A key interviewee who had professional engineering experience both in the commercial and humanitarian engineering sector highlighted the development of their problem solving abilities through their work in humanitarian situations. This provides evidence to suggest that not only does humanitarian engineering attract individuals with creative characteristics, but also develops the also. Further synthesis of the interviewee's responses around creativity can be found in figure 4.5 (see section 4.5).

Creativity is a skill that is essential within the engineering discipline (Harrison 2012; Watson *et al.* 2015), this is not in question. Yet different engineering tasks require different levels of creative input. For example, a task to build an average house in the UK is to an extent standardised, with building regulations and off-the-shelf components that are standardised. Whereas, within a small village in Himalayan mountain range, where raw materials are limited by logistics, an engineer is faced with a need for a more creative approach that looks at using the available resources to provide shelter and other amenities. The scenarios presented through the EWB Challenge discussed within the stakeholder interviews in section 4.3, and others used in RedR's training, present students with not only engineering problems to solve creatively, but also cultural barriers, logistical issues, and religious factors to overcome prior to an solution being implemented successfully and sustainably.

The relationship between creativity and engineering is important, despite each being very different concepts, with creativity subjectively driven, whilst engineering is more technically and numerically driven (Tierney *et al.* 1999). Yet without creativity, the development of new technical innovations to solve simple and complex problems would not be possible. The increased levels of creativity found within the humanitarian engineering sample, therefore can be considered an advantage to these students. Research conducted by Agogue *et al.* (2015) highlighted that creativity within engineering was important, and suggested that the background of individuals would impact upon the levels of creativity these individuals displayed. This study contributes to this previous study by highlighting that these students studying humanitarian engineering have increased levels of creativity, due to the nature of the engineering problems they are faced with.

The discovery that the level of creativity within Humanitarian Engineering students, acts as an indicator for their increased ability to meet Chartered Engineer status in future assessments, over the general engineering control group. Creativity is clearly stated in two of the UK-SPEC competencies. Firstly, focusing on the development technology and continual development of systems, and, secondly, the use of creativity to “maintain and enhance the quality of the environment and community, and meet financial objectives” (Engineering Council 2015:29). As well as the benefit to meeting the competencies of UK-SPEC, the development of creativity is also a recommended area of development in all academic disciplines, not just business based ones (Penaluna and Penaluna 2009). Therefore this study opens up a potential line for further research into why creativity exists in higher levels within these humanitarian engineering students? The answers to this question may allow for enterprise educators to further develop creativity education within engineering faculties globally.

5.2.3. Independence

The need for independence/autonomy within the humanitarian engineering sample group was found to be significantly higher than the general engineering sample group. For further detail upon the statistical analysis of this data, please see section 4.4. Within the observations independence appeared as both positive and negative factors. From a positive perspective, at points the students were able to effectively work as unique parts of a team that has separate functions. However when trying to bring the team together to collate the results and finalise the scenario solution, friction was apparent between group members who had previously been observed working effectively on their own task. These findings, whilst agreeing with the existence of independence within the humanitarian engineering students, suggest that independence is not necessarily always a positive factor and can be disruptive.

Throughout the interviews with humanitarian engineering academics, students and professionals, independence as a characteristic was identified on several occasions. A professional engineer stated that engaging with humanitarian engineering activities was partly about “gaining independence at the end of the line” (Interview 10). This suggests there is a desire to be more independent and not be restricted by regulations and bureaucracy that can be found within larger organisations. This links up with the kind of thinking often associated with push and pull factors of starting one's own business, where the lack of independence is pushing an individual out of company and towards setting up their own. This association with entrepreneurship and independence is also apparent when respondents were asked what they see the characteristics of an entrepreneur as being. A full synthesis of respondents based upon independence can be found in figure 4.6 (see section 4.5).

Independence is not only discussed in reference to the humanitarian engineers themselves, but also the people they are setting out to assist. Following an interview with a humanitarian engineering academic, it was highlighted that by the engineer delivering a solution, it should be the aim to support that community to develop autonomy. So for example, perhaps a village is in need of fuel, yet the nearest supplies are some distance away in another community. The humanitarian engineer could provide a solution that takes waste and converts it into a fuel, leaving the community to live more independently from others (Ong 2015).

The other key links to independence within the interviews was the repeated discussion around individual group work. Within the engineering courses discussed with participants, the difference between group work and individual projects was highlighted as being important to the integration of the EWB Challenge, as both aspects are needed to support student experience within both a team working and independent setting in their future careers.

Throughout the observations, there were no clear indications of independence. As the activities were all team based and mandated by learning facilitators, it is likely that this would have restricted any opportunity to observe independent behaviour.

The existence of the humanitarian engineer can often be regarded as one that requires independence of decisions and higher management processes. Within examples of humanitarian field work (Munoz and Mitchem 2012; Ong 2015), the humanitarian engineer has been seen to work away from hierarchical structures that can limit flexibility, and instead work in small groups to achieve an appropriate engineering solution. Although in some instances restrictions are in place, upon resources, finance and knowledge, there is a need to overcome these restrictions through being comfortable in an environment.

The existence of independence within an engineering context, is highlighted as being a positive factor for engineers to remain within the sector long term (Jackson *et al.* 1993). With humanitarian engineering students displaying significantly higher levels of independence than their other engineering peers, it is suggested that greater numbers of these individual will stay in engineering following graduation, therefore alleviating the deficit of engineering skills within the UK (Perkins 2013).

Whilst independence within engineering roles has been stated as being positive, there is no mention of it directly within the UK-SPEC (unlike a number of the other characteristics discussed within this chapter). Given the previous research stating a connection between engineer longevity and independent working, this may be an opportunity for independent working to be integrated within UK-SPEC. However, independence within the workplace will not always rely on an individual engineer’s competencies, rather the organisation itself and its working policies. Therefore, by further integrating independent working in more engineering firms and preparing student engineers to work both independently and within a group, this can further enhance engineering both in the UK and globally.

5.2.4. Internal Locus of Control

Following the statistical analysis of the internal locus of control statements within the questionnaire, the results stated that humanitarian engineering students had higher levels of internal locus of control than the general engineering control group, with a significance value of 0.00. The humanitarian engineering sample also had a significantly higher level of internal locus of control than the enterprise student sample.

Those students engaged with humanitarian engineering at the EWB Challenge final event, displayed optimistic approaches to the tasks and language. However, on observation of the humanitarian engineering elective module, the level of optimism appeared to be in an external locus of control rather than internal. This contradiction between the questionnaire results and observations, could be explained by a number of factors, however further research would be required to make appropriate conclusions and was not the focus of this investigation.

Within the interviews, a number of responses were presented that highlighted the existence and need for existence of internal locus of control within engineers. Whilst broad in nature, multiple academics referred to student engineers as having a passion for change and they are looking to change the world. This focus on change from the respondents provides further support to the alignment of internal locus of control within engineering education. This evidence should be utilised to support further integration of entrepreneurship development within engineering education. For a full synthesis of the internal locus of control results, please see figure 4.7 (see section 4.5). Alternatively for full interview transcripts, see appendix 4.

This, therefore, shows that the students engaged in humanitarian engineering education perceive the environment around them as one that can change under their influence, rather than one is imposing forces upon them. This is understandable given the scenarios found within the EWB Challenge and humanitarian examples discussed by Ong (2015). Within traditional engineering situations, although not standardised solutions, the existence of building regulations and guidelines can lead solutions within a similar direction. These regulations restrict the individual and their control upon the external factors. Whereas within the humanitarian scenarios discussed within the literature review (see section 2.2) an individual with a higher internal locus of control is required to influence the situations found. In the bio-digester example discussed by Ong (2015) this was an issue that the communities had lived with for many years. However through the use of local materials and expert knowledge this system could be developed to create methane for cooking. The existence of a higher level of internal locus of control in these humanitarian engineers is positive for multiple reasons.

- Within the humanitarian engineering field, change is a necessary process to manage evolving scenarios and problems. Factors such as emergency, disaster, culture, gender and religion can all create movement in a situation that may require adaption of an engineering solution in order to improve long term sustainability. This being said, the existence of a higher internal locus of control in these humanitarian engineers is beneficial within all aspects of engineering, both in the humanitarian field, as well as more commercialised engineering projects.
- The existence of higher levels of internal locus of control within the humanitarian engineering sample group, suggests a positive impact upon these engineers and their future careers. Building upon Keller's work into the

benefits of internal locus of control within engineers, this research proposes that these humanitarian engineering students have indicated the early potential to create increased numbers of publications and patents. This higher level of internal locus of control within these humanitarian engineering, it can be inferred that these students display higher levels of work satisfaction within their future careers, which in turn supports the global need for engineers to remain within the sector (Organ and Greene 1974).

5.2.5. Need for Achievement

As presented in section 4.4 there is a significant difference between humanitarian and general engineering results, with the humanitarian engineering students having the higher need for achievement of the two. The qualitative results supported these findings with interviewees stating that they believed they and others they had worked with had a high need for achievement (interview 10). The competition factor that was observed within both the Humanitarian Engineering elective module and EWB-UK Challenge final further evidences the existence of this need within the humanitarian samples. The weakness in these qualitative results however is the lack of comparison with non-humanitarian samples. Whilst it does not weaken the overall findings of this research, it would provide an improved level of understanding between these two groups, and is therefore discussed within chapter 6.

Whilst the stereotypical view of the entrepreneur is that there is a need to generate wealth and live a luxurious lifestyle, this is not overarching meaning of need for achievement. Need for achievement is about the small and big achievements in a career that can range from generating wealth to doing a task that is enjoyed. Within the humanitarian engineering field significant achievements are discussed in multiple examples from Ong (2015) and Vandersteen *et al.* (2011). The achievement of engineering a solution to assist a disabled child to participate in games with their friend is an achievement that may not generate wealth, but provides emotional achievement and increased recognition (Ong 2015). These achievements are also being pursued by British charity Remap which connects skilled volunteers to helping those with disabilities. As volunteers, it is not that there is no financial achievement, rather in its place an emotional one to see a solution potentially changing an individual's life.

The difference with the general engineering sample group may be that they have more of a focus upon the financial reward of a career in engineering, rather than volunteering to use their skills and knowledge in a volunteering capacity.

On review of the UK-SPEC, there is no clear focus upon achievement within the competencies. This is also the case for CBHA Humanitarian Framework (Rutter 2011). Whilst both documents do not display a need for achievement within their text directly, it can be argued that individuals who aim to meet and exceed the competencies of both have a need for achievement. Some of the competencies may be easily achieved, whereas others may require significant effort the meet them, but the need for achievement is the driving force to halt procrastination and take action.

5.2.6. Perseverance

As the results in section 5.4 highlight, humanitarian engineering students presented a significantly higher levels of perseverance than the general engineering control group. Within the interviews, perseverance and its synonyms are only discussed in limited part, however, the discussion around them highlights key, potentially life-changing consequences. Firstly, a key characteristic observed by the respondent within humanitarian work is the need for patience, as situations can be more complex than first recognised (Interview 8). This, therefore, requires perseverance to move forward with the work, even if this is at a slower rate than usually anticipated. The need for discipline, rigour, and the ability to follow procedure was also highlighted as being factors that could mean the difference between life and death. Whilst following these procedures may require increased levels of perseverance, due to their complexity or irrelevance, if misunderstood there are scenarios such as conflict zones and emergency situations that could cause loss of life. For a full synthesis of the responses around perseverance, please see figure 4.11 (see section 4.5).

Within the observations, perseverance arose positively twice and negatively once. The positive perseverance with seen in multiple teams that maintained momentum throughout the two our activity to reach the end with a completed assignment. Yet within one of the teams, the level of perseverance was found to be lacking, as despite an initial level of engagement, the effort levels towards the task dropped as the session continued.

Given the nature of humanitarian engineering, presenting problems that in some countries may be a simple engineering fix, whilst in other instances, cultures, resources, technologies and expertise are different. These, often unique scenarios, require the engineers to utilise their knowledge to approach the problem from a different angle that is likely to require more time, patience and therefore perseverance.

Within UK-SPEC, there are no direct connections with the need for perseverance, although it might be inferred given the level of continued effort and action required to meet all of the competencies required within it. Engineering solutions, whether in Western society or developing countries, often require a degree of perseverance to develop, prototype, refine and establish a solution. These findings suggest that the humanitarian engineering students are showing higher levels of this perseverance, to overcome problems that are outside of their past experience and perhaps their cultural background too.

5.2.7. Risk Taking Propensity

The propensity for an individual to take risks is found to be significantly higher within the humanitarian engineering sample, when compared to the general engineering control group. Despite the quantitative results suggesting the increased level of risk taking within the humanitarian engineering students, there was no risk taking characteristics observed within either of the observation sessions.

Risk was only highlighted to a small extent within the interviews (10 and 12); however, the findings do provide insight into the connection of risk-taking between humanitarian engineering and the changing engineering curriculum. The link between UK-SPEC and risk is discussed by interviewee 6 focusing upon the reasons behind implementing the EWB Challenge at their university. The response highlighted that there was a drive from UK-SPEC's focus upon the assessment of risk as a measure of a chartered engineer amongst other competencies that were seen as benefits of the EWB Challenge to the students' learning. Another of the interviews (interview 8) highlighted an incident encountered when they were robbed at gun point in South America. Where some people could have been put off by working in environments with this level of risk, the interviewee who continues to work in field humanitarian work, continued their work. This reaffirms the existence and need for a risk-taking propensity to work within a humanitarian environment.

Within the humanitarian contextual examples discussed, risk has been a factor in many of the scenarios. The emergencies where RedR are involved, include higher levels of risk, such as the risk of an after-shock following an earthquake that could put further lives in danger. Non-emergency based humanitarian work has also been evidenced as having increased risks, within changing cultural contexts, that may make a normal action within the Western society one that may increase risk in a different culture. Therefore, the ability to take risks with both their own life and those that are being served, is outweighed by the need to achieve results that will equalise the disadvantage that exists within each scenario.

The existence of risk within the entrepreneurial literature is well documented (QAA 2012; Curth *et al.* 2012), however, when compared to the key engineering education documents such as UK-SPEC, there are different conclusions to be made. Within an entrepreneurial context the acknowledgement of risk and making decisions based upon risks, is considered key to many of business success stories. However, within UK-SPEC a more cautious approach is taken to focus on the management of risks and hazards, rather than taking decisions based on these risks. This approach is understandable given the responsibility engineers have to those that they provide solutions to, as in many cases a risk not anticipated could lead to sinister consequences. Yet when compared to the CBHA Humanitarian Framework competencies (Rutter 2011), risk is perceived differently.

The CBHA humanitarian competencies (Rutter 2011) highlight both sides of the risk argument, in a similar way to the entrepreneurial businesses risk propensity. Whilst like UK-SPEC, there is a need to anticipate and evaluate risks to ensure the reduction of negative consequences. There is also the need to move forward through taking risks, as the competency below highlights:

- "Take calculated risks to improve performance" (Rutter 2011:38).

Increased levels risk taking propensity within the humanitarian engineering sample group in this instance, may be a disadvantage when looking to meet the UK-SPEC competencies; as there is a focus on risk aversion and management over risk-taking. This research suggests an update to future UK-SPEC editions to encompass risk-taking propensity as a positive step in engineering. Whilst keeping a balance between risk management and risk-taking, as seen in the CBHA Humanitarian Framework (Rutter 2011).

5.2.8. Self-Efficacy

From the quantitative data, self-efficacy is the only entrepreneurial characteristic discussed that is significantly higher within the general engineering control sample group, compared with the humanitarian engineering sample. The level of self-efficacy within the general engineering sample group is similar to the enterprise sample group, with no significant difference between the two.

The interviews suggested that self-efficacy was something that existed within the students studying Humanitarian Engineering, as one of the interviewees (Interview 7) highlighted a specific group that were self-assured when working upon the EWB Challenge activity. However, it was also noted within the interview process that lack of confidence was an issue within engineering as a whole, with critical thinking not being as focused upon as it should (Interview 3). A full synthesis of the positive and negative points relating to self-efficacy can be found in figure 4.13 (see section 4.5).

The need for self-efficacy within the humanitarian engineering field was anticipated to be high, given the often independent and isolated scenarios discussed by Ong (2015) and Vandersteen *et al.* (2010). However, the findings suggest that the humanitarian engineering students have significantly lower levels. A potential explanation of this difference might be the connection of self-efficacy to hubris (arrogance) and also the lack of empathy (Hmieleski and Baron 2008). As discussed within one of the interviews, the effect of apathy upon the students was suggested as being a reason for disengagement. This would suggest that individual's lower levels of self-efficacy may suggest whether they have a higher propensity for humanitarian-based work.

On review of the both UK-SPEC (Engineering Council 2015) and the CBHA Humanitarian Framework (Rutter 2011), there is no direct focus upon the need for self-efficacy or self-confidence within either, although tenuous links can be inferred. UK-SPEC, however, does highlight the need of being confident in managing interpersonal situations, which suggests that the general engineering sample group have the advantage within this specific competency. It could be argued that there is a need for this self-efficacy to make an engineer believe in themselves and prolong their education, meet the competencies of UK-SPEC and continue their professional development. Moreover given the discussion above regarding empathy and apathy, is there an optimal level of self-efficacy that may separate those engineers engaged in humanitarian work and those that are not?

Ponton *et al.* (2001) suggest that academic staff's secondary role is to construct the student's self-confidence throughout their learning. So is this process within the humanitarian education sector lacking within delivering this self-efficacy? This study suggests that whilst building up a student's self-efficacy is a positive impact of academia, there is an optimal level for it, which may be the mean value of both the humanitarian and general engineering sample groups combined questionnaire results.

5.3. Non-significant results

Through the statistical analysis of the 11 entrepreneurial characteristics measured within this study, three of the characteristics are found to have no significant difference between the humanitarian engineering sample group and the general engineering (control) sample group. These three characteristics are tolerance to ambiguity, leadership and opportunity recognition.

Leadership was a characteristic noted on occasions throughout the observations of in-class humanitarian activities and therefore it was hypothesized that this would be matched by quantitative data. However, there was no significant difference between the humanitarian and general engineering sample groups, which linked with the both sets of interviews, as there was no contextual discussion of leadership. With the need for leadership featuring throughout UK-SPEC (as discussed in section 2.3.7.1, these results would suggest that whilst these characteristics do exist within humanitarian engineering students, there is no difference between other engineering students. Therefore the humanitarian engineering students do not have advantage over their general engineering peers in the leadership qualities desired within UK-SPEC and professional engineering careers. The interview data yielded little evidence supporting leadership either positively or negatively. One of the engineering professionals (interview 9) suggested that they try to be a leader, however still finds themselves as a follower too, which corresponds appropriately to the non-significant results found in the quantitative results. Please see figure 4.8 (see section 4.5) for a full synthesis of the interview data related to leadership.

The characteristic **opportunity recognition** was found to have no significant difference between the humanitarian and general engineering sample groups. UK-SPEC highlights in competency A2 the need to "identify constraints and exploit opportunities for the development and transfer of technology within own chosen field" (Engineering Council 2015:39). By contrast, the CBHA competencies (Rutter 2011) do not discuss opportunity recognition directly, and therefore it is not necessarily something expected within work in the humanitarian field. This data, therefore, presents the case that those students studying Humanitarian Engineering are not at an advantage with their level of opportunity recognition, compared to their peers. If both groups were to be assessed for Chartered Engineer status using the UK-SPEC, the results suggest there would be no significant difference between each of the sample groups. Whilst there was a lack of difference between the engineering sample groups, there is evidence from the interviews that highlight that the professional and academic engineers perceive opportunities as being available, although in the students cases not always acted upon. For a summary of the opportunity recognition interview responses, please see figure 4.11 (see section 4.5).

Tolerance to ambiguity was only highlighted briefly within observations and interviews as it identified as a difficult characteristic to identify, without a longitudinal study approach. Despite this, one of the interviewees (Interview 10) who works within a large engineering business, noted that tolerance to ambiguity was a characteristic that they had and was important for both their humanitarian work and engineering day job. Therefore the results from the statistical analysis echoed the same point. However, the similarity between the humanitarian and general engineering sample groups are not what was expected. Given the complex nature of humanitarian engineering demonstrated throughout the literature (Amadei and Sandekian 2010; Vandersteen *et al.* 2010; Mitchem and Munoz 2010; Ong 2015), from emergency situations that require fast thinking to save lives, to longer-term problems that require an engineer to anticipate factors that may not be prevalent in their home countries. These humanitarian engineers are expected to have a higher level of tolerance for ambiguity, as highlighted within the CBHA Humanitarian Framework (Rutter 2011), on several occasions as noted below:

- "Recognise stress and take steps to reduce it" (Rutter 2011:6)
- "Remain constructive and positive under stress to be able to tolerate difficult and sometimes threatening environments" (Rutter 2011:6).

UK-SPEC, by contrast, does not make direct mention of a need for tolerance to ambiguity in engineers. This research therefore suggests that this be an area for development within future editions of the competencies, due to ambiguity found in many engineering scenarios. This tolerance to ambiguity does exist within both of the sample groups and neither group presents a higher propensity to it than the other.

5.4. Impacts

Whilst there are many smaller impacts of these findings discussed within this chapter, this section presents the key overarching impacts of this study.

The research conducted into what individuals understand by the term humanitarian engineering has presented a broad message within the UK centric interviewees and focus group, despite a majority of them being active within the EWB Challenge programme. The lack of definitive response potentially causes confusion with students searching for these types of courses within HEIs. However, the benefit of multiple definitions across the interviewees allows for each institution to specialise in certain aspects of humanitarian engineering, such as disaster relief and disability rehabilitation, community development. As a consequence of the findings of this research Coventry University has adopted a broad, multi-faceted definition towards humanitarian engineering that also encompasses the Univerity's dual-focused faculty, Engineering and Computing.

> *Humanitarian Engineering and Computing is about using engineering and computing in a culturally sensitive and sustainable way to address issues that limit opportunities and development in communities. It can be applied on a local, national or international level and in not necessarily restricted to being a reaction to a disaster or crisis (Fitzpatrick 2014).*

Within the single institution setting of Coventry University, these findings highlight the increased level of entrepreneurial characteristics within the faculty in which engineering sits (the faculty of Engineering and Computing). This faculty has traditionally seen lower levels of engagement within the enterprise and entrepreneurship support packages on offer through the university such as mentoring, enterprise electives and business start-up grant funding (Hill 2014). Therefore, given the significantly higher levels of the seven of the 11 measured entrepreneurial characteristics within the humanitarian engineering students, the use of this knowledge to target entrepreneurial support packages may encourage higher levels of engagement, start-ups and potential job creation.

From a broader national and international perspective. The literature discussed in section 2.3, as well as the pilot study data on business ownership has highlighted that the existence of these characteristics increases the propensity to establish businesses. Therefore, the students that are displaying these higher levels entrepreneurial characteristics are more likely to create businesses and have an impact upon local, national and international economies.

5.5. Study Limitations

Whilst a number of key findings have been stated throughout this research, it is essential to recognise the limitations of the work.

One of the key issues that may limit this work is the self-selecting nature of the research method employed. Many individuals were approached to take part in this research, however, it was not mandatory and therefore not all completed the questionnaire or volunteered to take part in interviews. Although this factor may cause a positive bias from participants, the same approach was taken for all participants, therefore keeping the approach consistent.

Another potential issue is the single institution approach to this study. Whilst the benefits of utilising researching students that had actively chosen to study humanitarian engineering was an important factor in isolating specific sample groups, it is recognised that Coventry University may be an unusual situation. However, given the follow up research undertaken through interview, the data collected from eight universities suggest that these characteristics are also visible within these students also. Additionally to this, the interviews conducted with engineering professionals who had previously been engaged in humanitarian engineering activities, also highlighted an increased level or change in many of the characteristics being measured. For further research, the methodological process employed within this study will be employed in other institutions in order to further validate the results.

Why do the students studying humanitarian engineering choose the topic in the first place? There may be multiple reasons for this, these could include, true interest, a lack of other options, peer pressure amongst others. In future work, this question would be developed further to assess the reasons for engaging with the topic.

The adaption of the questionnaire statements developed by Gasse and Tremblay (2006) may have affected the reliability of the original methodology. In order to measure whether this is the case, the pilot study discussed in section 3.5.3 was conducted. These results highlighted that the updated methodology continued accurately to indicate characteristics that display a higher propensity to starting and running businesses, which was the initial purpose of the questionnaire. The interviews also supported a number of the findings from the quantitative data.

The final key limitation to this study is the use of a cross-sectional approach, rather than longitudinal approach. The data provided by this study highlights the increased level of characteristic within seven of the 11 categories, however, only highlights that individuals with these characteristics are attracted to humanitarian engineering, rather than actually being changed by the humanitarian engineering engagement. Suggestions for further work in line with this limitation are discussed in section 6.2.

5.6. Summary – Implications for Policy and Practice

Through the discussion of these results, implications for policy and practice have been identified that add to the literature within the humanitarian engineering and entrepreneurship areas of research.

With the support of this research study, Coventry University has joined the UNESCO UNITWIN Network programme. This global programme actively promotes dialogue through global universities to develop capacities through knowledge alliances (UNESCO n.d.). The university has joined the programme with the primary objective of sharing knowledge and experience of the humanitarian engineering movement. As a part of this process, the increased networks have been shown to support the development of policy, both on a national and international level. Given the results discussed within this research, Coventry University's input into the UNITWIN programme not only impacts the way in which humanitarian engineering education is utilised pedagogically, but also the increased levels of the seven entrepreneurial characteristics could be further pinpointed within engineering faculties globally. Through this identification of engineering students with these characteristics, enterprise resources could be more effectively allocated.

The targeting of entrepreneurial support within engineering faculties, both at Coventry University, could be further developed both in other individual HE institutions, as well as informing national policy. With the limited resources in HEIs and the drive to integrate enterprise further into education, the results of this study highlight a group of engineering students that have increased levels of entrepreneurial characteristics, that have shown increased inclination towards starting up and/or running a business or becoming intrapreneurs (Pinochet 1985) within an existing organisation.

As the propensity of business start-ups is higher within individuals with the 11 characteristics discussed by Gasse and Tremblay (2004) and Caird (2013), the increased levels of seven of the entrepreneurial characteristics of humanitarian engineering students suggest that more businesses will be created, with more employment and increased economic impact.

6. Conclusions

As this thesis draws to a close, it is essential to review the key findings noted within the discussion and summarise the responses to the research questions. The findings of this research highlight a clear association between the Engineering and Entrepreneurship disciplines that goes beyond helping engineers with ideas to set up businesses. The key conclusions of this thesis are discussed below.

Humanitarian Engineering is a term that is associated with multiple discussions of need and support. The ongoing theme presented within the discussions, recognises a need to help those that are disadvantaged within society. Whilst there are those that require immediate support (such as emergency and disaster victims) there are also communities who have become accustomed to their plight and therefore do not register as high on the media coverage gained. Given the findings discussed within chapter 5, it is recommended that HEIs, charities and policy makers adopt a broad definition to humanitarian engineering that not only focuses upon specific needs such as disaster relief and famine, but the multiple disadvantages that are faced worldwide, whether that be the need for the basic necessities detailed the Millennium Development goals or those individuals in our local communities that may be trying to manage their disability.

By adopting a broader definition within policy, further consolidation of efforts can be gained by stakeholders who are affected by these disadvantages and those institutions who can assist them. Whilst the findings of the research reflect some of those discussed by others globally, this research into what humanitarian engineering means to the UK context for academics, students and professional engineers provides an image that was previously missing. This process has already begun with the participation of Coventry University within the UNESCO UniTwin network to support the development of humanitarian engineering with other institutions and in turn further convince policy makers of the need.

Whilst the development of humanitarian engineering is positive for those beneficiaries of the engineering solutions, there is also a long-term benefit to the students engaging within it. Engineering education through humanitarian contexts allows students to perceive the scenarios, not simply in a UK context where a structure exists, but globally speaking where resources, culture and other factors can be different. Also given the data collected through the interview process highlights the employability prospects of students engaged in humanitarian engineering, as those interviewed highlighted the benefits of what they had previously learnt in their current engineering roles.

Humanitarian engineering students have significantly higher levels of seven of the 11 characteristics considered to be entrepreneurial in nature when compared to general engineering students. These characteristics are shown to not only be visible within the quantitative self-assessment questionnaire at Coventry University but also the observations and interviews conducted throughout this study. Whilst the humanitarian engineering students have significantly higher levels of two of the 11 characteristics, compared to students studying entrepreneurship based modules, humanitarian engineering at Coventry University does attract students with a number of the key enterprise characteristics referred to in the literature review. The quantitative results gained at Coventry University are shared to an extent in the broader fields measured from the seven case studies undertaking the EWB-UK Challenge.

The findings stating that the students displayed seven entrepreneurial characteristics highlights a potential opportunity for further connection between engineering and entrepreneurship, by both HEIs and policy makers. With the low percentage of engagement with entrepreneurship within engineering disciplines (Hill 2014), this research proposes that enterprise support departments consider the targeting of engineers who engage within humanitarian engineering. Whilst this should not be the sole focus of the support, given the evidence presented towards these characteristics and their impact upon the development businesses, it is suggested that further start-ups and jobs can be created.

Another opportunity here is identifying the opportunity for development of these characteristics within engineering as a whole. As characteristics such as creativity, internal locus of control and perseverance were found to be significantly higher within the humanitarian engineering sample group, how could these characteristics be boosted within the general engineering sample? For HEIs and policy makers this is a question that could further develop enterprise activities within engineering faculties.

6.1. Contributions to Knowledge

One of the requirements of a Doctoral thesis is its ability to add to the body of knowledge and provide researchers a further level of findings and debate that can inform research in this field. The key contributions of knowledge addressed within this thesis are discussed in the following sections.

This study has produced an understanding of the term humanitarian engineering, from a UK context, following interviews and focus groups with students, academics and professional engineers. Previously, literature produced within North America and Australasia has made insights into humanitarian engineering, only with this study has a greater understanding been developed based around the UK centric viewpoint.

Quantitative evidence states that students at Coventry University studying humanitarian engineering display higher levels of entrepreneurial characteristics than their counterparts studying engineering disciplines other than humanitarian engineering.

A contextual discussion that interlinks the importance of humanitarian engineering, engineering development (referring to the gaining of Chartered Engineer status) and entrepreneurship has also been shown. The evidence presented shows that those engaged with humanitarian engineering have higher levels of entrepreneurial characteristics, which have clear associations within a number of the UK-SPEC competencies as well as presenting an opportunity. This opportunity would allow enterprise education to be focused on a group of students that already have inclinations toward entrepreneurial tendencies. This is not to say the humanitarian engineering students should be the only engineers to be offered entrepreneurship support, however with the limited resources available within HEIs, this would help maximise the long-term benefit.

The data gathered throughout this study has led to Figure 1.1 (see section 1.3) being adjusted to represent the results gained within the research. Figure 6.1 demonstrates that given the majority of entrepreneurial characteristics being measured being higher in humanitarian engineering students; there is an increased level of overlap within humanitarian engineering students, compared with their engineering peers.

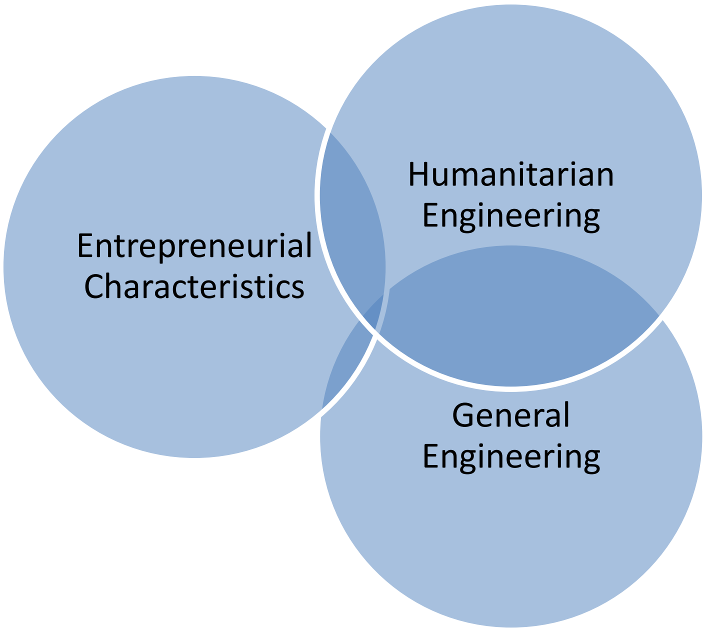

Figure 6.1 Adjusted Venn diagram representing relationship between the three core research elements

What are the implications of this for engineering education in the UK and globally? As stated throughout the literature review, engineers need to look beyond the standard principles of their discipline and consider key factors such as ethics, resources, appropriate technology, sustainability, economics and more. Simultaneously, universities are actively integrating enterprise and entrepreneurship into their internal activities and long-term strategies, as can be seen from a number of the cases discussed by Anderson *et al.* (2014).

Therefore through the implementation of humanitarian engineering activities within faculties, engineers are aligned with a more entrepreneurial mind-set. This leads to more effectively equipped engineering graduates that may be more inclined to start their own businesses or be more effective in the businesses of others, as seen within the interview data.

6.2. Further Work

Whilst this research has responded to the original research questions highlighted in the introduction, more questions and suggestions for further work have been raised that will be considered in the sections below.

6.2.1. Characteristic Development

Whilst the data collected within this research states that humanitarian engineering attracts individuals with significantly higher levels of seven of the 11 characteristics considered to make an individual entrepreneurial, the data cannot speculate as to whether these characteristics develop whilst studying Humanitarian Engineering modules. As many of the characteristics measured throughout this project are linked to the development of employable engineers, knowing how these characteristics change over a period of time would highlight certain topics and/or pedagogies that differently impact upon these changes.

A potential developmental route for the method would be to use the current questionnaire, with updates following the Cronbach Alpha data and deliver it to students at different stages throughout modules, academic years and entire degree courses. As a longitudinal study, this will evaluate whether there is a change over time and potentially further support the Humanitarian Engineering and Enterprise agendas in HE.

6.2.2. Expanding Geographical Samples

Coventry University was chosen for this study due to its growing specialisms in both Humanitarian Engineering and Enterprise. Yet to further develop this study and gain more insight as to the relationship between humanitarian engineering and entrepreneurial characteristics, as argued by this study, more universities could be included in the next stage of the research.

As a relatively young institution, Coventry University is growing in both research (92 per cent of research considered to be world-leading, internationally excellent or recognised internationally in REF2014) and in student experience (Times Higher Modern University of the Year 2014, 2015, 2016). Therefore this combined with the wide range of specialisms across both the UK and globally could yield different results in different institutions. To further this research an exact replica of the original data collection process could be employed in other universities around the world, in order to identify any fluctuations and look to assess the reasoning behind these results.

This new data would look to further expand the body of knowledge as to the impacts of teaching humanitarian engineering in multiple global contexts, and lead to advanced development of pedagogical approaches. As there are multiple teaching approaches employed to implement the EWB-UK Challenge in the case studies discussed in chapter 4, there are likely to be visible impacts of these different styles that could further influence how humanitarian engineering is further disseminated throughout the HE sector globally.

6.2.3. Gender

Throughout the collection of the data used within this study, the gender of participants was recorded. Through the use of this data, there are a number of research opportunities that could be developed, to further develop the discussion produced by Brown and Joslin (1995) on the differences between genders in college students. The first route would be the development of research into the gender balance that humanitarian engineering attracts. The gender bias within engineering education has been male dominated, whilst humanitarian engineering appears to attract a more neutral number of female and male students.

Another opportunity that could be developed from this research is the differences between the genders based upon the entrepreneurial characteristics measured. The characteristics of both engineering- and non-engineering-based students could illuminate the opportunities for resources and policy to target specific genders.

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Appendix 1:
Current & Forthcoming Research Outputs

Below are research outputs generated through the use of research conducted in this study.

Hill, S. (2016) '*Entrepreneurial Characteristics in STEM: A Higher Education Institution Perspective' European Conference on Innovation and Entrepreneurship (ECIE). To be held September 2016 in Finland.*

Hill, S. and Miles, L. (2015) *'Humanitarian Engineering: A Route to Systemic Entrepreneurship Application across Africa'*. In *Systemic Entrepreneurship.* Ed. by Maas, G., and Jones, P. London: Palgrave

Hill, S. Wick, D. Lockyer, J. and Miles, L. (2014*) 'Longitudinal Case Study of the changing Characteristics of Student Entrepreneurs Participating in SPEED Plus at Coventry University'*. *Institute of Small Business & Entrepreneurship (ISBE) Conference.* Held 5-6 November 2011 in Manchester, UK

Hill, S. and Miles, L. (2012) *'What do Students understand by the term 'Humanitarian Engineering''*. In Centre for Engineering and Design Education (eds) *Conference proceedings for EE2012,* 'Engineering Education UK Conference'*.* Held 18-20 September 2012 at Coventry University, UK. Loughborough: Loughborough University.

Appendix 2:
Ethical Approval Documentation

<u>**Participant Information Sheet**</u>

Information about the project/Purpose of the project
This project has been devised to understand the relationship between humanitarian engineering and entrepreneurial characteristics. The key question being asked is whether humanitarian engineering attracts and/or nourishes entrepreneurial personality traits.

Why have I been chosen?
You have been chosen to participate within this research as you fit into one of the following categories:

- Student engaged in humanitarian engineering
- Student not engaged in humanitarian engineering
- An engineer engaged in humanitarian engineering

Do I have to take part?
You are not obliged to take part in this research. It is completely up to you whether you wish to participate.

What do I have to do?
You are asked to complete these questions with honest responses, once completed you may be contacted to request participation in a follow up interview.

What are the risks associated with this project?
There are no foreseen risks to you or others by participating in this research.

What are the benefits of taking part?
By taking part in this research you will have available to you a comprehensive entrepreneurial personality assessment available to you, in order to enhance your own personal development.

Withdrawal options
You can withdraw up to 30 days after your initial response from this research.

Data protection & confidentiality
All data provided will be password protected at all times and at no point during or after the research will individuals named responses be made public, in order keep anonymity.

What if things go wrong? Who to complain to

If you are not satisfied in the way that things have gone in the research, you may complain to either the researcher direct:
Simon Hill – hills10@uni.coventry.ac.uk
Or for higher matters please contact:
Dr Liz Miles – aa7679@coventry.ac.uk

What will happen with the results of the study?
The results of this study will be used as part of a PhD Thesis primarily, however may also be used in publications, within the field. All results will remain anonymous.

Who has reviewed this study?
This research study has been reviewed by Dr Liz Miles and (Ethics reviewer)

Further information/Key contact details of researcher and supervisor
Should you have any questions or concerns, you contact either of the below individuals:

Researcher - Simon Hill – hills10@uni.coventry.ac.uk
Supervisor - Dr Liz Miles – aa7679@coventry.ac.uk

REGISTRY RESEARCH UNIT

ETHICS REVIEW FEEDBACK FORM

(Review feedback should be completed within 10 working days)

Name of applicant: Simon Hill ....

Faculty/School/Department: [Faculty of Engineering and Computing] Engineering Knowledge Management Division ....

Research project title: Understanding the connections with Humanitarian Engineering and Entrepreneurial Characteristics

Comments by the reviewer

Evaluation of the ethics of the proposal: Approved as low risk based on reference from Supervisor below: 'Questionnaires checked by the supervisor etc all consent forms obtained. No concerns in effect this is a low risk project'.
Evaluation of the participant information sheet and consent form:
Recommendation: (Please indicate as appropriate and advise on any conditions. If there any conditions, the applicant will be required to resubmit his/her application and this will be sent to the same reviewer).

X	Approved - no conditions attached
	Approved with minor conditions (no need to re-submit)
	Conditional upon the following – please use additional sheets if necessary (please re-submit application)
	Rejected for the following reason(s) – please use other side if necessary
	Not required

Name of reviewer: Anonymous..

Date: 21/11/2013...

Ref: P18526

Informed Consent Form

This project has been devised to understand the relationship between humanitarian engineering and entrepreneurial characteristics. For all information regarding to this research study, the uses of the data and your rights as a participant; please see the participant information sheet.

Please tick

1. I confirm that I have read and understood the participant information sheet for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason. ☐

3. I understand that all the information I provide will be treated in confidence ☐

4. I understand that I also have the right to change my mind about participating in the study for a short period after the study has concluded (*30 days after the date entered below*). ☐

5. I agree to take part in the research project ☐

Name of participant: ....

Signature of participant: ....

Date: ....

Name of Researcher: ....

Signature of researcher: ....

Date: ....

Online Informed Consent

'Participation in the study is entirely voluntary; you can withdraw from the survey at any point of time, without giving a reason for doing so. Please be assured that the **information you provide will remain strictly confidential and anonymous**. Answers will be reported so that no individual or organization will be identifiable from any publication presenting the results of the survey. By responding to the questionnaire, your consent to take part in the study is assumed and that you agree to the use of anonymised data in publications. If you would like to have further information about the project, please contact me via email Simon Hill hills10@uni.coventry.ac.uk & Dr Liz Miles aa7679@coventry.ac.uk

REGISTRY RESEARCH UNIT

ETHICS REVIEW FEEDBACK FORM

(Review feedback should be completed within 10 working days)

Name of applicant: Simon Hill ....

Faculty/School/Department: [Engineering & Computing] EC Engineering Management

Research project title: Understanding the connections between Humanitarian Engineering & Entrepreneurship

Comments by the reviewer

Evaluation of the ethics of the proposal:

Approved and finalised with the permission of the Faculty Leader Ray Farmer.

Evaluation of the participant information sheet and consent form:

Recommendation:
(Please indicate as appropriate and advise on any conditions. If there any conditions, the applicant will be required to resubmit his/her application and this will be sent to the same reviewer).

X	Approved - no conditions attached
	Approved with minor conditions (no need to re-submit)
	Conditional upon the following – please use additional sheets if necessary (please re-submit application)
	Rejected for the following reason(s) – please use other side if necessary
	Not required

Name of reviewer: Anonymous ....

Date: 07/12/2012 ....

Ref: P8790

Appendix 3:
Questionnaire

Positional Questions

1. What is your full name?
2. What email Address
3. How Many UCAS Points did you achieve prior to entering Higher Education?
4. What is your gender? (Please select)
5. What is your ethnic origin? (Please select)
6. What is the primary focus of your course? (Please select)
7. What is your undergraduate course title?
8. What faculty does your course sit? (Please select)
9. Do any of your family members run their own business?
10. Have you ever been involved in humanitarian engineering?
11. Have you ever been involved in enterprise/entrepreneurship education?
12. Have you ever run your own business?

Characteristics Questions

Please review each of the following statements, and indicate your preference towards each using the multiple choice options.

	Strongly Agree	Agree	Disagree	Strongly Disagree
Working on a project that is recognised by others is important to me.	○	○	○	○
Working for others does not bother me.	○	○	○	○
Following strict parameters allows me to be more effective within a project.	○	○	○	○
When one of my projects fails, I find it easy to get over it and move on.	○	○	○	○
When starting a new project, I always have a successful end in mind.	○	○	○	○
Coping with stress is quite easy for me in difficult situations.	○	○	○	○
Possibilities are easy to see when looking at problems.	○	○	○	○

Developing my career is in my own hands.	◌	◌	◌	◌
To move forward in my career I need to take action.	◌	◌	◌	◌
Taking calculated risks is important to my future.	◌	◌	◌	◌
Grasping opportunities is what I do.	◌	◌	◌	◌

	Strongly Agree	Agree	Disagree	Strongly Disagree
I don't enjoy leading others.	◌	◌	◌	◌
I enjoy being able to choose my own working schedule.	◌	◌	◌	◌
Seeing projects through to the end is often difficult for me.	◌	◌	◌	◌
My instincts have led me down wrong paths, so generally I distrust them.	◌	◌	◌	◌
Working on ambiguous and uncertain projects is difficult for me.	◌	◌	◌	◌
When problems arise, I look to find a variety of solutions.	◌	◌	◌	◌
In my eyes, success in the projects I'm working on can change by making different choices.	◌	◌	◌	◌
I don't need to take lots of action to get where I want to be in my career.	◌	◌	◌	◌
I know the success of a project sometimes requires sacrifice, however this is not something I'm always willing to make.	◌	◌	◌	◌
Achieving the goals of project is important to my momentum.	◌	◌	◌	◌
Opportunities may be available to	◌	◌	◌	◌

progress, but I am happy with where I am.				

	Strongly Agree	Agree	Disagree	Strongly Disagree
Being praised for a job well done is not essential to me.	○	○	○	○
Being the leader is important to me.	○	○	○	○
Flexible working times make me less effective in my work.	○	○	○	○
Even when projects are tough I like to get to the end.	○	○	○	○
Presenting my ideas to others worries me.	○	○	○	○
Difficult projects that I am involved in, often make me feel restricted.	○	○	○	○
Being able to imagine new solutions is a trait I feel I have.	○	○	○	○
Taking risks is no different to buying a lottery ticket, its all chance.	○	○	○	○
Thinking is important, but action is where the results are gained	○	○	○	○
Taking risks does not bother me.	○	○	○	○
Opportunities are everywhere.	○	○	○	○

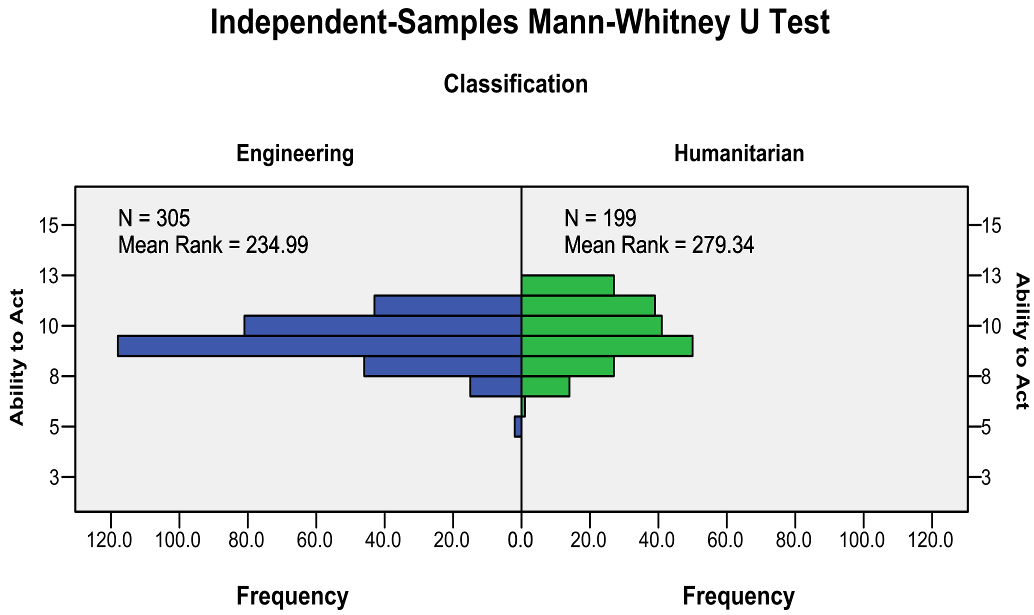
Appendix 4:
Interview Transcripts

Due to the 12 interview transcripts length, an electronic anonymised copy is available on the CD ROM attached:

Appendix 5:
Mann-Whitney U-Test Graphics

The following eleven figures present the Mann-Whitney U Tests, conducted between the humanitarian engineering and general engineering student sample groups. The summary data for these figures can be found in Table 4.5 (see section 4.4.3). The figures below present a number of details generated automatically through the SPSS software package, however the key piece of information within each is the asymptotic significance (2-sided test). The figures are organised in alphabetical order of the characteristics (action orientation, creativity, independence, internal locus of control, leadership, need for achievement, opportunity recognition, perseverance, risk taking propensity, self-efficacy and tolerance to ambiguity). The comparison data of the enterprise and general engineering groups have been summarised within the work, however are not provided here.

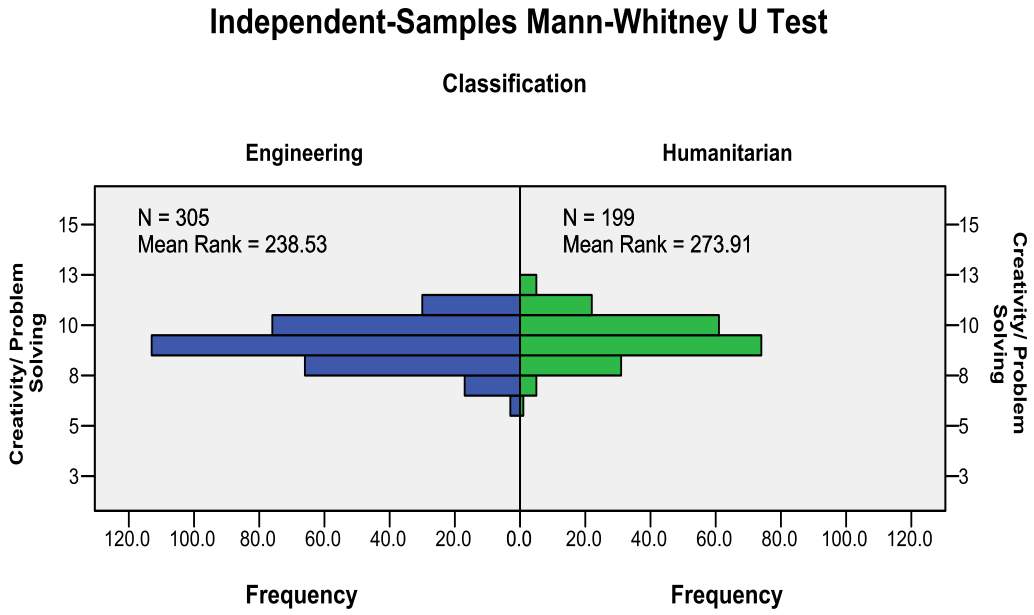
Action Orientation



Total N	504
Mann-Whitney U	25,007.000
Wilcoxon W	71,672.000
Test Statistic	25,007.000
Standard Error	1,550.415
Standardized Test Statistic	-3.445
Asymptotic Sig. (2-sided test)	.001

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Action Orientation

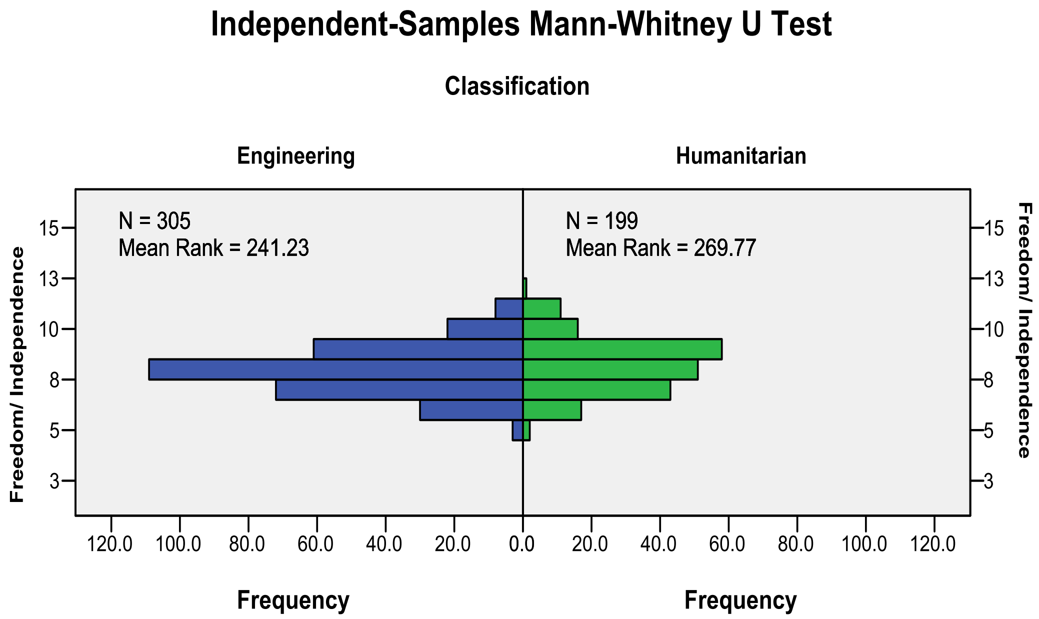
Creativity



Total N	504
Mann-Whitney U	26,086.000
Wilcoxon W	72,751.000
Test Statistic	26,086.000
Standard Error	1,533.382
Standardized Test Statistic	-2.779
Asymptotic Sig. (2-sided test)	.005

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Creativity

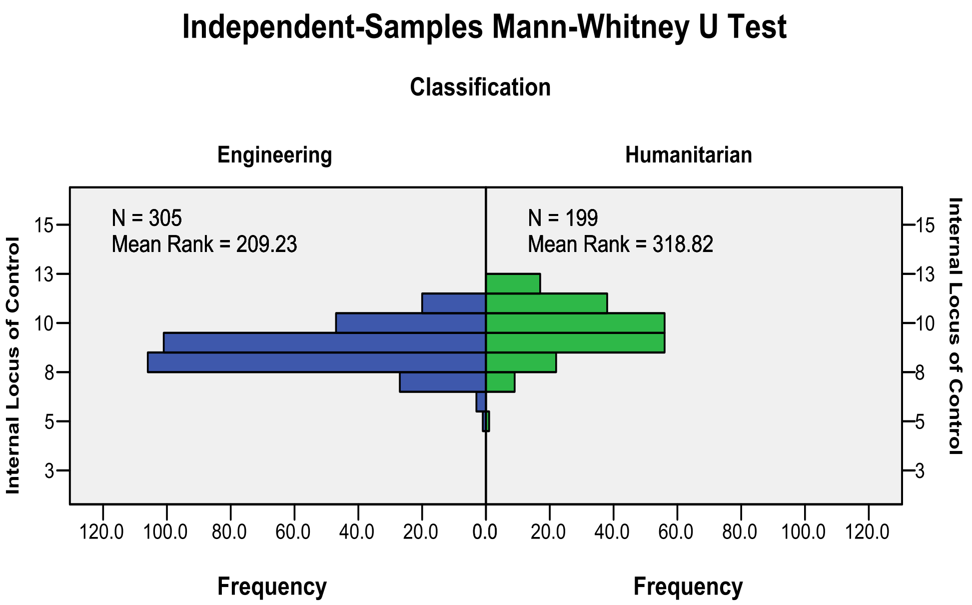
Independence



Total N	504
Mann-Whitney U	26,911.500
Wilcoxon W	73,576.500
Test Statistic	26,911.500
Standard Error	1,550.892
Standardized Test Statistic	-2.215
Asymptotic Sig. (2-sided test)	.027

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Independence

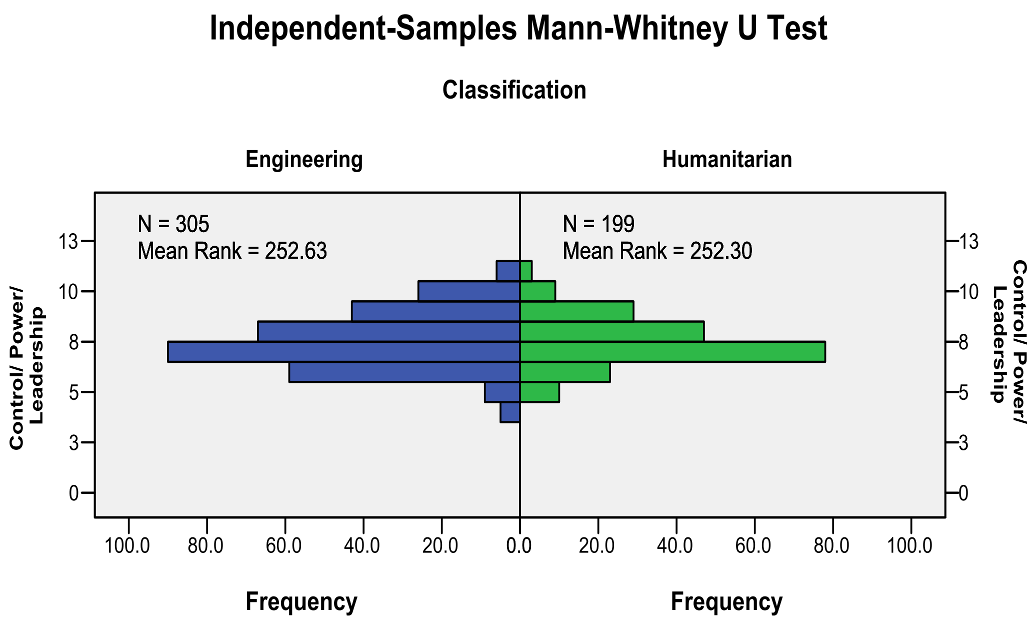
Internal Locus of Control



Total N	504
Mann-Whitney U	17,150.000
Wilcoxon W	63,815.000
Test Statistic	17,150.000
Standard Error	1,551.929
Standardized Test Statistic	-8.504
Asymptotic Sig. (2-sided test)	.000

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Internal Locus of Control

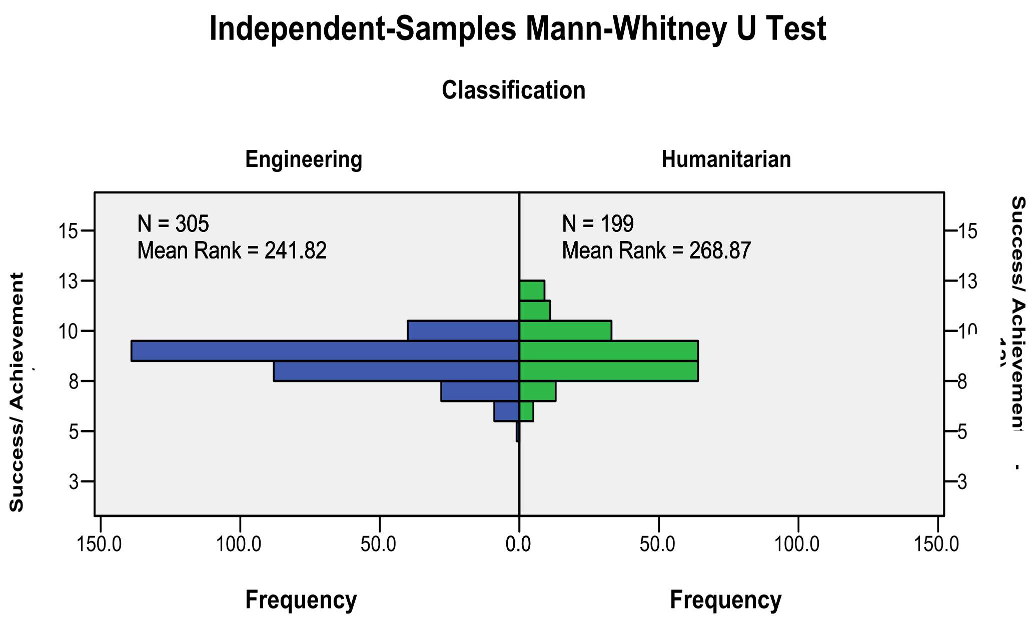
Leadership



Total N	504
Mann-Whitney U	30,386.500
Wilcoxon W	77,051.500
Test Statistic	30,386.500
Standard Error	1,552.624
Standardized Test Statistic	.025
Asymptotic Sig. (2-sided test)	.980

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Leadership

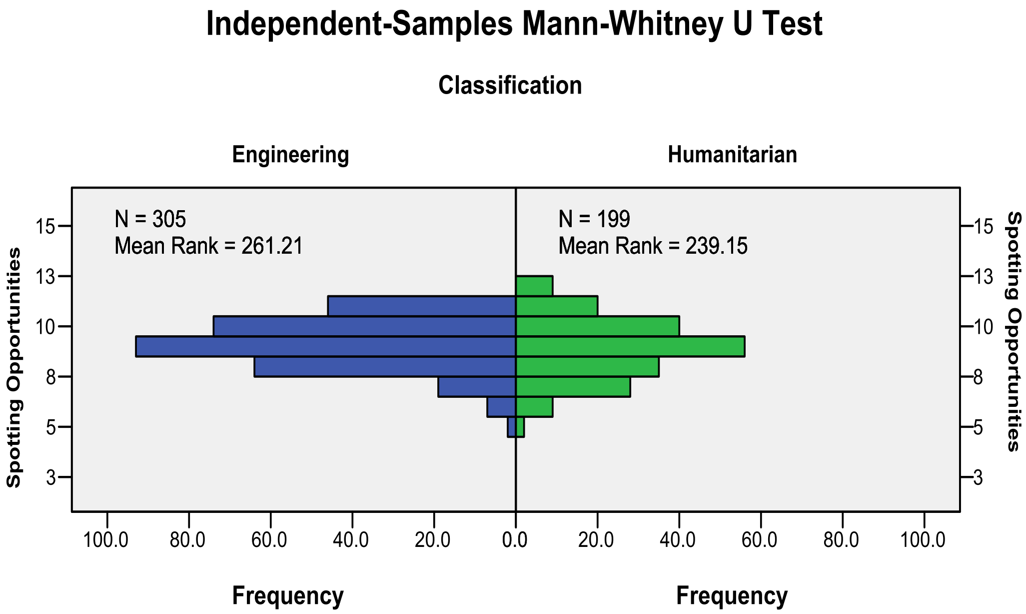
Need for Achievement



Total N	504
Mann-Whitney U	27,090.500
Wilcoxon W	73,755.500
Test Statistic	27,090.500
Standard Error	1,519.229
Standardized Test Statistic	-2.144
Asymptotic Sig. (2-sided test)	.032

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Need for Achievement

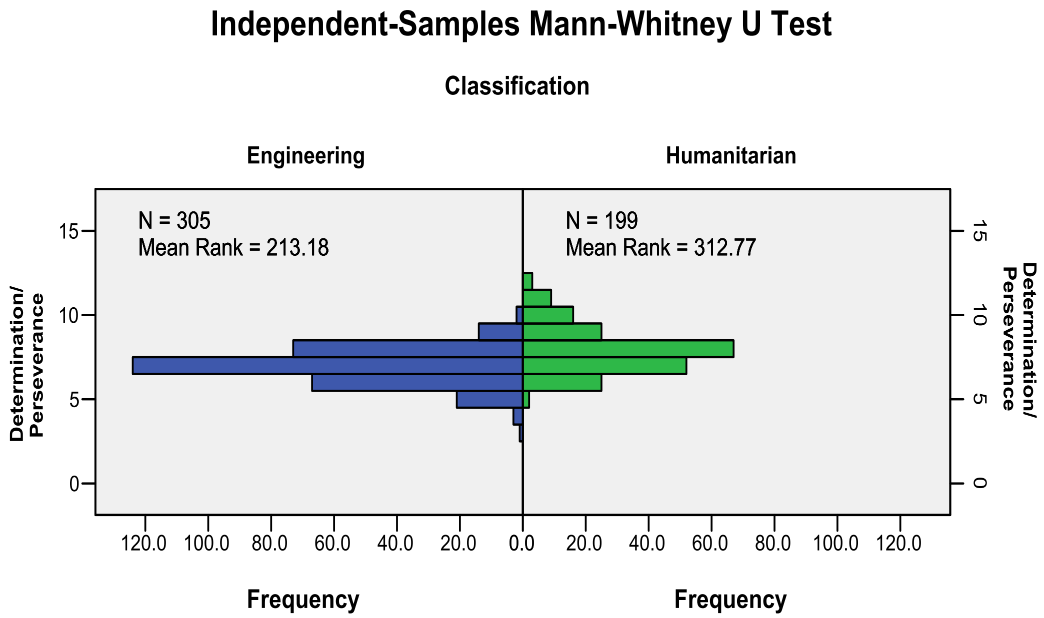
Opportunity recognition



Total N	504
Mann-Whitney U	33,004.500
Wilcoxon W	79,669.500
Test Statistic	33,004.500
Standard Error	1,559.307
Standardized Test Statistic	1.704
Asymptotic Sig. (2-sided test)	.088

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Opportunity Recognition

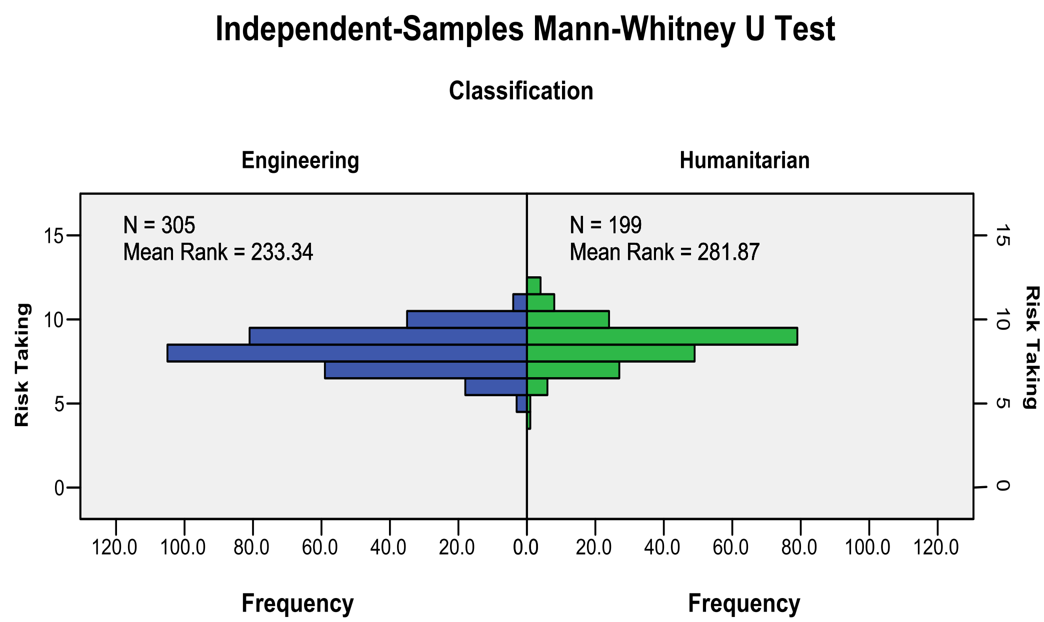
Perseverance



Total N	504
Mann-Whitney U	18,354.000
Wilcoxon W	65,019.000
Test Statistic	18,354.000
Standard Error	1,540.664
Standardized Test Statistic	-7.785
Asymptotic Sig. (2-sided test)	.000

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Perseverance

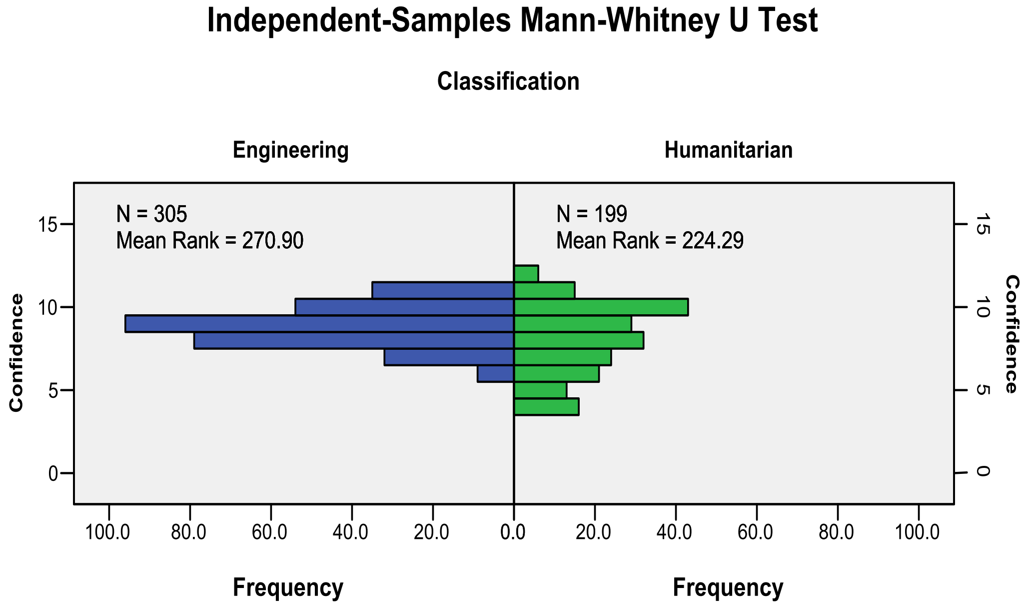
Risk taking propensity



Total N	504
Mann-Whitney U	24,503.000
Wilcoxon W	71,168.000
Test Statistic	24,503.000
Standard Error	1,543.557
Standardized Test Statistic	-3.786
Asymptotic Sig. (2-sided test)	.000

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Risk Taking

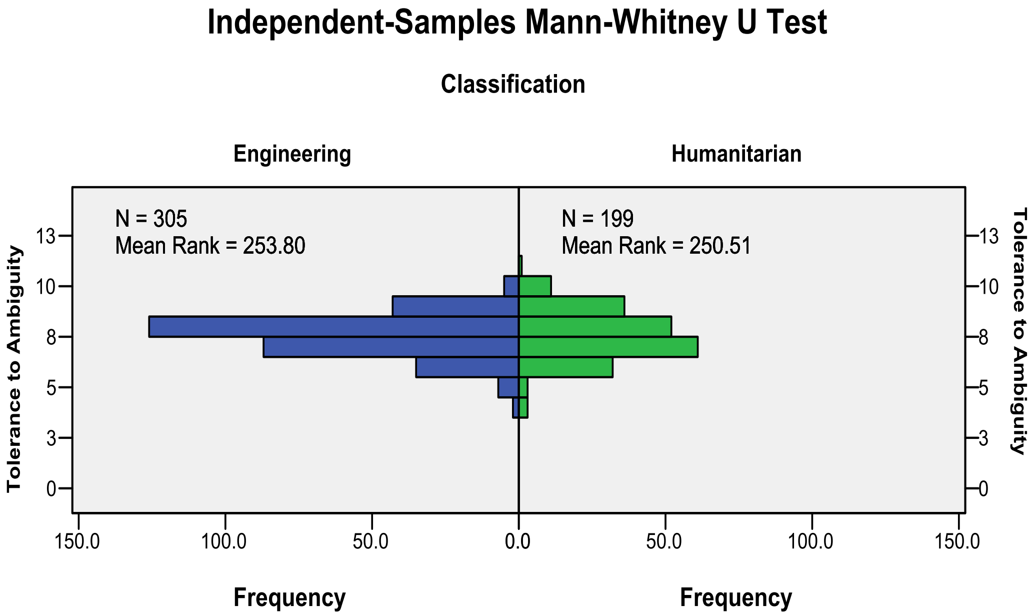
Self-efficacy



Total N	504
Mann-Whitney U	35,961.000
Wilcoxon W	82,626.000
Test Statistic	35,961.000
Standard Error	1,569.436
Standardized Test Statistic	3.577
Asymptotic Sig. (2-sided test)	.000

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Self-Efficacy

Tolerance to ambiguity



Total N	504
Mann-Whitney U	30,743.500
Wilcoxon W	77,408.500
Test Statistic	30,743.500
Standard Error	1,536.593
Standardized Test Statistic	.258
Asymptotic Sig. (2-sided test)	.797

Mann-Whitney U Test between Humanitarian & Engineering Samples assessing Tolerance to Ambiguity