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ENHANCING ENGINEERING EMPLOYABILITY IN THE 21st CENTURY; HANDLING UNCERTAINTY AND COMPLEXITY THROUGH 'NEW ENTREPRENEURSHIP'

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Abstract: Universities, professional bodies and governments prioritise graduate employability and seek these through 'generic', 'soft', 'entrepreneurial' and 'transferable' skills. The UK's Higher Education Academy published a list of 39 *'aspects of employability'* to assist in the *'examination of curricula from [the] point of view of employability'* (Yorke and Knight, 2006). These capabilities generally align with good pedagogical practice and include for example, 'critical analysis', 'reflectiveness', 'creativity' and 'coping with complexity'. However, some clearly appear to focus on interests that align more specifically with business aspirations such as for example, 'stress tolerance', 'influencing', 'arguing for and/or justifying a point of view'.

This paper argues that universities, given their role and duty as leaders in the development of knowledge and understandings have a consequential responsibility to develop employable graduates who will be equipped to lead and change their (future) organisations for societal good (and ultimately for the good of organisations themselves) rather than to be led in seeking to continually serve up whatever type of 'oven ready graduates' that the market economy may envisage. It proposes that, in the wake of the increasing complexity and uncertainty that surrounds 21st century society, engineers' employability will be best realised by graduates who possess additional capabilities to the aforementioned, such as for example, metacognition (learning how to learn), independent critical thought, recognising inherent uncertainty and complexity, resilience, humility and openness to (integrating) new perspectives. Such engineers embody Gibb's (2002) 'new entrepreneurship' paradigm, contrasting with a narrow conception of entrepreneurship based primarily around business and new venture management.

Keywords; engineering graduate employability, new entrepreneurship, complexity, uncertainty, efficiency, resilience, 21st century.

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1. INTRODUCTION

'Transferable', 'generic' and 'soft' skills are to an increasing extent being considered a core requirement for graduate engineers, particularly in terms of promoting graduate employability. In the European context, the European Federation of National Engineering Associations (FEANI) requires 'transferable skills' as one of six programme outcomes at both bachelors and masters level. This is replicated at national and disciplinary levels; for example, the United Kingdom's

Engineering Council requires that all (bachelors and masters level) graduates possess 'general transferable skills' as one of four general learning outcomes, while institutions such as the Institution of Chemical Engineers and the Institutions of Mechanical Engineers reiterate these requirements through their respective accreditation documentation (Byrne *et al.*, 2010).

This increased focus on developing skills associated with enhanced employability is not confined to engineering education alone. This trend represents a general tendency across all university programmes and disciplines and one which has accompanied greater general participation levels across third level education (Maher, 2004). One manifestation of this can be found in the publication by the United Kingdom's Higher Education Academy of a list of some thirty nine *'aspects of employability'*, which are designed to assist in the *'examination of curricula from [the] point of view of employability'* (Yorke and Knight, 2006). These attributes are grouped under three clusters: 'personal qualities, 'core skills' and 'process skills' (see Appendix A).

2. GRADUATE EMPLOYABILITY

The skills, over and above presumed discipline specific skills, that are typically identified as those which assist 'graduate employability' include 'transferable', 'generic', 'entrepreneurial' and 'soft' skills. Moreover, these attributes are by and large, ones that are also required to equip graduates with the skillset which will enable them meet professional ethical responsibilities towards broader societal good. Indeed working towards societal good is the overarching role of the engineering professional as envisioned by Bucciarelli (2008) and others (Johnson, 1989; Beder, 1998; Conlon 2008) ahead of one which views the role of engineering as merely to supply 'value neutral' 'guns for hire'. It is on this basis that Bucciarelli (2008) suggests that *if we, as engineering faculty, still claim that it is our job and responsibility to teach 'the fundamentals', it's time explicitly to recognise that what is fundamental to engineering practice goes beyond scientific, instrumental rationality.'*

It will be argued in this paper that while the development of generic skills are a vital trait for the contemporary engineering graduate (and hence needs to be reflected in programmes of study), that the prime and explicitly stated driver for this ought to be to equip graduates with the necessary skills to help advance societal good, rather than for any narrower conception which merely seeks to serve industry perceived 'needs', for example by producing 'oven ready' graduates who require as little as possible further training post recruitment. For if graduates are equipped with the attributes and vision which will enable them to accept the broader mantle of serving societal good, such graduates will clearly serve business and their own organisations well through the longer term. On the other hand, a graduate directed simply to address the short term perceived needs of business may not be best positioned to comprehend any broader societal role, nor indeed serve their organisations longer term interests around sustainability, survival and flourishing. In short, while serving business needs is a valid and worthy role of the formation of engineering graduates, this should not be the only role but should represent a subset of a broader professional role which is one directed at the long term flourishing of society. This approach is ever more pressing for engineering graduates of the 21st century, faced as they are with grand societal challenges that are presenting in areas such as energy, water and food provision as well as the effects of climate change, all emanating from a societal construct which is inherently unsustainable (Byrne and Fitzpatrick, 2009).

Moreover, an engineering profession whose overarching mission is to facilitate long term societal good is one which is likely to enjoy spin off benefits in the form of a larger cohort of well-motivated students choosing to enter the engineering profession. A study of first year engineering students at Imperial College London from a range of disciplines found that *'making a difference to the world'* – presumably a positive one, was the number one aspiration among female engineering students prior to their choosing to enrol with the engineering profession, while it was second only to the prospect of inventing something new among males (Alpay *at al.*, 2008). This was also found to be the number one driver behind future civil and aeronautical engineering students and the second highest aspiration among all other branches, including chemical (who valued financial security more), computing (ditto), electrical & electronic engineering (ditto) and mechanical (inventing something new) engineering students.

3. 'NEW ENTREPRENEURSHIP'

'Entrepreneurship' skills are among the transferable skills which aid engineering employability through the development of leadership and innovation skills among graduates (Nichols and Armstrong, 2003). In the context of the broader societal remit of the engineering profession as described above, an approach characterised by Gibb's 'new entrepreneurship' (Gibb, 2002) could be considered as an appropriate model. This conception of entrepreneurship is one which incorporates a broader definition of the term than that which is traditionally employed involving a *'narrow business orientation'* and one which is characterised as involving a heroic figure who is typically an impatient owner of start up fast growing tech centred businesses where external capital is involved. Gibb argues that this conception simply '*does not have full empirical or conceptual underpinning'*. Why for example, do organisations which are not growing or those facing decline or fighting to retain market positions not require even more entrepreneurial behaviour than the typical case? Gibb instead proposes to characterise entrepreneurship as something that is required in the face of *'uncertainty and complexity in the task and broader environment'*. At a stroke, with this definition of a new entrepreneurship, Gibb extends the necessity for entrepreneurship from what was previously *'solely the prerogative of business'* to a behavioural requirement right across society *'for example, priests, doctors, teachers, policemen, pensioners and community workers and indeed, potentially everyone in the community.'*

Given the increasing levels of uncertainty and complexity that increasingly pertain across society (including through engineering practice) through the 21st century, and the subsequent need for critical thought, humility and being open to adopting and integrating new perspectives, the need for such an entrepreneurial spirit has never been stronger. Gibb links such ongoing increased uncertainty and complexity with the broader global context of *'the globalization and competitiveness agenda'*. This aligns with research in the field of industrial ecology which proposes that a sole focus on an agenda based on increased efficiency, throughput, economies of scale, productivity, ongoing incremental short term increases, monoculture and survival of the fittest can lead only to unsustainable system collapse. Natural (and human/societal) systems displaying long term sustainability on the other hand, balance the aforementioned against the opposing traits of resilience, redundancy, diversity, creativity, uncertainty and interconnectivity (Princen, 2005; Korhonen and Seager, 2008; Ulanowicz *et al.*, 2009). Indeed such insights from complexity can provide invaluable lessons in the realm of global financial and economic systems as they can predict as inevitable the collapse of any such systems which measure success based

exclusively on indicators of throughput and scale such as for example, GDP growth (Goerner *et al.*, 2009; Lietaer *et al.,* 2010). A complexity informed approach also reveals that the only type of 'equilibrium' that can be attained through highly efficient (deregulated) markets is when they no longer exist, as the ongoing global banking and financial crisis from 2007 has demonstrated.

An ability to meet and even embrace uncertainty and complexity, and hence exhibit new entrepreneurship skills is a feature which may not only satisfy the short term business and organisational interests of engineering graduate employers, but may also help satisfy their less obvious long term interests of sustainability and survival. This approach finds common ground with the concept of the 'new engineer' proposed by Beder (1998), which seeks to embrace uncertainty and complexity through approaches which can be characterised as being in the realm of post normal science (Funtowicz and Ravetz, 1994). It also aligns with the pursuit of a broader sustainability informed ethos across higher education (Yarime et al, 2012) and the concept of the 'New American University' as pioneered and promoted by Arizona State University president Michael Crow (Crow, 2010).

It is in this context that it is claimed that a well developed appreciation of the roles, nature, context and inter-relationships between uncertainty, risk, complexity, entropy, resilience, redundancy, creativity, connectivity, emergence and sustainability may constitute a key part of the ultimate employability skill set for the 21st century engineer seeking to work for the ongoing good of society.

4. CASE STUDY: APPLICATION

4.1 First year engineering module

The author taught and devised part of a first year module common to all engineering students from 2011-12 entitled 'Professional Engineering Communication and Ethics' (code: PE1006). As a professional introductory module, its objectives include *'developing [students'] appreciation of professional ethics through application in complex problems and case studies.'* The module was delivered to 132 students through a mixture of formal lectures as well as tutorial/facilitation group sessions where students worked with their respective groups in defining, analysing and tackling a selected complex 'wicked' societal problem (chosen from a list of 26 problems to which engineers could meaningfully contribute). Assessment included a group wicked problem assignment group report and presentation to peers/lecturing team as well as an individual reflective report on the module. One of the key aims in designing the module was to aid understanding of the context, nature and prevalence of uncertainty and complexity as these relate to engineers/engineering practice, to help students become more comfortable with handling these, and develop students' critical thinking and openness to new and challenging perspectives; essentially promoting Gibbs 'new entrepreneurship' among students.

4.2 Employability attributes survey

At the conclusion of the module, students were invited to fill in a survey to gauge i) how they considered each of the UK HEA employability attributes were developed throughout the module and ii) how important they themselves deemed each to be in relation to employability. The survey was carried out to ascertain to what extent students perceived issues around complexity, uncertainty, creativity and adaptability were covered in the module and to what extent they felt

that these were important employability traits. A total of 47 surveys were returned, of which 39 were fully or partially completed from a total of 132 students, representing a response rate of 30%. In the context of this work, two groups of employability aspects were identified from the 39 listed. One group contained those deemed to be most closely aligned to the Gibb's concept of the 'new entrepreneur' as one who can handle complexity and uncertainty (adaptability, creativity, ethical sensitivity, coping with complexity, problem solving, comfortable with uncertainty, context, breadth of knowledge). The other group were identified as attributes more closely aligned to the traditional business oriented view of the entrepreneur (stress tolerance, commercial awareness, influencing, arguing for/justifying a point of view). Collated results are presented in Table 1 with the latter group presented in bold.

Please tick an appropriate box which reflects your opinion in terms of both Employability and the PE1006 module for each of the statements below.	How well Developed is this quality in PE1006 module?				
(Key to abbreviations: Imp't: Important; Dev'd: Developed)	Very well Dev'd	Quite well Dev'd	Some-what Dev'd	Not very Dev'd	Not at all Dev'd
Adaptability: ability to respond positively to changing circumstances and new challenges.	8	17	12	2	
Stress tolerance: ability to retain effectiveness under pressure.	6	13	16	3	1
Creativity: ability to be original or inventive and to apply lateral thinking.	9	17	12	1	
Commercial awareness: operating with an understanding of business issues & priorities.	7	6	16	8	1
Ethical sensitivity: appreciates ethical aspects of employment and acts accordingly.	10	17	8	2	
Coping with complexity: ability to handle ambiguous and complex situations.	9	17	10	2	
Problem solving: selection and use of appropriate methods to find solutions.	6	20	8	3	
Influencing: convincing others of the validity of one's point of view	6	12	15	5	
Arguing for and/or justifying a point of view or a course of action	5	13	15	5	1
Comfortable with uncertainty: ability to understand, cope with and appreciate uncertainty	6	18	13	1	1
Context: ability to view things in context and appreciate different contexts and viewpoints	9	18	11		
Breadth of knowledge: seek a broad knowledge base across disciplinary boundaries	12	7	15	3	2

Please tick an appropriate box which reflects your opinion in terms of both Employability and the PE1006 module for each of the statements below.	How Important is this quality for Employability?				
(Key to abbreviations: Imp't: Important; Dev'd: Developed)	Very Imp't	Quite Imp't	Some-what Imp't	Not very Imp't	Not at all Imp't
Adaptability: ability to respond positively to changing circumstances and new challenges.	18	14	4	1	
Stress tolerance: ability to retain effectiveness under pressure.	18	14	4	1	
Creativity: ability to be original or inventive and to apply lateral thinking.	14	18	2	1	
Commercial awareness: operating with an understanding of business issues & priorities.	5	15	14	1	
Ethical sensitivity: appreciates ethical aspects of employment and acts accordingly.	13	17	7		
Coping with complexity: ability to handle ambiguous and complex situations.	16	12	6	2	
Problem solving: selection and use of appropriate methods to find solutions.	23	7	6		
Influencing: convincing others of the validity of one's point of view	9	12	15		
Arguing for and/or justifying a point of view or a course of action	8	19	8	2	
Comfortable with uncertainty: ability to understand, cope with and appreciate uncertainty	8	21	6	1	
Context: ability to view things in context and appreciate different contexts and viewpoints	13	16	7		
Breadth of knowledge: seek a broad knowledge base across disciplinary boundaries	15	12	8	1	1

Table 1 Students perceptions of coverage and relevance of selected employability aspects.

4.2 Student perceptions

The students appeared to recognize the emphasis put on developing skills associated with 'new entrepreneurship' and the 'new engineer'. In general, all the attributes listed were deemed to be

either quite or very important in terms of employability, whereas the degree to which they were developed throughout the module was considered less striking. This is unsurprising since the module represents just about 2% of the degree programme as a whole. Also unsurprisingly, 'problem solving' was deemed to be the most important skill with respect to employability, followed by 'adaptability', 'stress tolerance', 'coping with complexity', 'ethical sensitivity' and 'context'. The responses given by both individual students and collectively bore a close relationship between what students perceived was covered well within the module and what they perceived to be important employability traits. Given the name and nature of the module, it is hardly surprising that 'ethical sensitivity' ranked highly in terms of its perceived development through the module, as did 'context', 'creativity', 'coping with complexity' and 'adaptability', followed by 'problem solving' and 'comfortable with uncertainty'. On the basis of these responses, it appears that the key aim within the module of helping students achieve greater understanding of complexity and uncertainty and the ability to deal with each at least had the potential to be met. On the other hand, the skills more closely associated with the traditional entrepreneurial model did not rank relatively highly either in terms of their perceived development within the module or in terms of perceived employability, with the exception of 'stress tolerance' as a key employability quality. There is likely to be significant influencing factors going on here; the ethos, emphasis and delivery that pertain throughout a particular module are likely to influence the way students perceive the world around them and the value they place on certain aspects and attributes. This is particularly true for a first year class where this module is essentially their first contact with and formal introduction to the world of engineering. This is not a problematic condition though, if one accepts the conception of engineering practice as an inherently value based endeavor (Bucciarelli, 2008).

4. RESULTS & CONCLUSIONS

This paper has argued that while the key role for engineering graduates must be to serve societal good, the required attributes to do this in the face of 21st century challenges tally well with employability traits, particularly those associated with Gibb's 'new entrepreneurship'. These include an understanding of the nature and ubiquity of complexity and uncertainty as well as the roles of creativity and resilience across engineering practice and broader society. Such an approach necessarily requires an appreciation of the broader context, a broad knowledge base, openness towards critical thinking and new perspectives and trans-disciplinary approaches to problem solving/resolving/dissolving, particularly in relation to global meta and grand challenges around (un)sustainability that are presenting in an increasingly complex 21st century society. A first year professional introductory module which has been developed and which aims to develop such skills is cited, where students appear to recognise value in this approach.

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APPENDIX A - UK HEA 'Aspects of Employability' (Yorke & Knight, 2006)

A. Personal Qualities

1 Malleable self-theory: belief that attributes [eg intelligence] are not fixed and can be developed.
2 Self-awareness: awareness of own strengths and weaknesses, aims and values.
3 Self-confidence: confidence in dealing with the challenges that employment and life throw up.
4 Independence: ability to work without supervision.
5 Emotional intelligence: sensitivity to others' emotions and the effects that they can have.
6 Adaptability: ability to respond positively to changing circumstances and new challenges.
7 Stress tolerance: ability to retain effectiveness under pressure.
8 Initiative: ability to take action unprompted.
9 Willingness to learn: commitment to ongoing learning to meet the needs of employment and life.
10 Reflectiveness: the disposition to reflect evaluatively on the performance of oneself and others.

B. Core Skills

11 Reading effectiveness: the recognition and retention of key points.
12 Numeracy: ability to use numbers at an appropriate level of accuracy.
13 Information retrieval: ability to access different sources.
14 Language skills: possession of more than a single language.
15 Self-management: ability to work in an efficient and structured manner.
16 Critical analysis: ability to 'deconstruct' a problem or situation.
17 Creativity: ability to be original or inventive and to apply lateral thinking.
18 Listening: focused attention in which key points are recognised.
19 Written communication: clear reports, letters etc written specifically for the reader.
20 Oral presentations: clear and confident presentation of information to a group [also 21, 35].
21 Explaining: orally and in writing [see also 20, 35].
22 Global awareness: in terms of both cultures and economics.

C. Process Skills

23 Computer literacy: ability to use a range of software.
24 Commercial awareness: operating with an understanding of business issues and priorities.
25 Political sensitivity: appreciates how organisations actually work and acts accordingly.
26 Ability to work cross-culturally: both within and beyond the UK.
27 Ethical sensitivity: appreciates ethical aspects of employment and acts accordingly.
28 Prioritising: ability to rank tasks according to importance.
29 Planning: setting of achievable goals and structuring action.
30 Applying subject understanding: use of disciplinary understanding from the HE programme.
31 Acting morally: has a moral code and acts accordingly.
32 Coping with complexity: ability to handle ambiguous and complex situations.
33 Problem solving: selection and use of appropriate methods to find solutions.
34 Influencing: convincing others of the validity of one's point of view
35 Arguing for and/or justifying a point of view or a course of action [see also 20, 21, 34].
36 Resolving conflict: both intra-personally and in relationships with others.
37 Decision making: choice of the best option from a range of alternatives.
38 Negotiating: discussion to achieve mutually satisfactory resolution of contentious issues.
39 Team work: can work constructively with others on a common task.