Engineering the Future:
A Multi disciplined approach.

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Abstract
Mechanical engineering embodies a considerable number of disciplines and a range of core principles. The professional standards are maintained by accrediting organisations within different countries. Engineers like to work in the real world and apply their skills to mechatronics, robotics and kinaesthetics amongst many other things; but, there are new developments in the global market place that question some of the processes inherent in engineering design. The evolving areas focus upon the areas of innovation and the ability to be creative, so as to be able to establish a USP (unique selling point) for research or a company's brand. There is a fundamental change that is needed in the education of the student engineer designer to ensure that there is some form of correlation between technical proficiency and creativity, so it is possible for them to be innovative: these two variables represent key areas within business and research acting as driving forces in the production of ideas and objects. There is a need for the engineer designer to adapt to today's business environment and to be aware of the changing working processes and technical convergences that are being applied in industry in 2010. Being able to understand the inherent values and practises in a number of disciplines today is important. Sometimes; the connections may originate from unlikely sources, for instance, the cross over between engineering design and art.

The authors represent an estimated 70 years of experience in engineering, design and art. They have trawled their collective experience and researched key areas to identify important concepts and variables that engineer designers should consider empathising with in the act of developing concepts, ideas and innovative products. The authors have identified ninety two variables that they consider to be important to the engineer designer. The variables originate from, design, psychology and art; combined, all of these areas help the individual to see the world from a number of different perspectives. The authors suggest that this research proffers a potential starting point to further define the theoretical construct and practise of being creative. Overall, today's engineer designer has to acknowledge that there are changes in working practises, including: inter-disciplinary research plus the technical and cultural convergences to maintain and aid the professional standards and core principles inherent within the occupation of the engineer designer. This paper is submitted with the purpose of stimulating debate concerning two of the most complex areas of design; the act of being creative and the process of designing in the world of the engineer.

Key words
Working processes, measurement, variables, definitions, cross disciplines approach, creative.

Introduction
In an article entitled, 'Pack Science off to Revive Wellspring of Creativity,' in the Times Higher Educational Supplement (2009:27)[1] Linda Wording asserted that, ' Asia wants to keep its bright scientists at home' and the author also suggests that it is,' a golden opportunity for us to leap ahead'. To some extent this is supported by Geoffrey Cossick within the same article (2009:28) the warden at Goldsmiths University of London stated, ''an innovative society thrives on creativity' and continues,' the skills the economy requires are inter disciplinary skills; the ability to make unexpected and creative connections.'

As far back as 2005 the UK government commissioned a number of papers to investigate the role creativity and its importance to the UK Economy. The Cox report [2] and The DTI Economics Paper NO 15 entitled, 'Creativity Design and Business Performance' [3] are some. The overriding

message was one that stated that creativity is important in business terms and in how it might be exploited for commercial reasons. The rationale is obvious, apart from advocating actions; has any real understanding of creativity been produced and what are the working practises of this creativity? As Vicky Pryce Chief Economics Advisor and Director General, Economics DTI Economic Paper NO 15 Creativity and Business Performance (2005) said in the foreword, the 'starting point for debate in how to promote creativity and design across the UK. More work is needed on definition and measurements. 'In the foreword to his report Sir George Cox (2005) stated that, 'the emphasis (*in the text*) is on the use made of creative skills by smaller businesses, with particular concern for manufacturing. For the purpose of the report he states, 'Creativity' is the generation of new ideas – either new ways of looking at existing problems, or of seeing new opportunities, perhaps by exploiting emerging technologies or changes in markets. 'The overarching purpose is, 'to help bring about a climate that encourages and supports greater creativity.' The Management and business in the Arab World is beginning to reflect this different approach It has been highlighted recently at the Fifth Arab Meeting for Small and Medium Industries under the theme, 'Building the Creative and Innovative Capacities of Small and Medium Industries' that took place in Algeria between 14 /15th March 2010.

The Problem

There seems to be some form of co-existence between politics and industry which suggests a working definition of the concept creativity; but where and how is the concept of creativity developed? For the purpose of this research creativity is considered from the perspectives of several domains, these being engineering, design and art. The focus of the work is to try and define some of the links between the connection between thought and practise. The fundamental question asked in this research is; is it possible to identify and produce some of the key working processes, relative to all areas that could act as a starting point for further research in this important domain. The concept of creativity is a complex one. Eysenck (1994: 86) [4] defined it as,' creativity refers to the ability to produce unusual, high quality solutions to problems, it has been argued that there are significant aspects of human intelligence which are not adequately assessed by intelligence tests'. Eysenck also explains that there are complex problems that seem to be an intrinsic part of the concept, 'Creativity is notoriously difficult to investigate in the laboratory. Many tests of divergent thinking or creativity are basically measuring originality rather than creativity, that is to say they assess the tendency to produce unusual solutions to a problem, but do not evaluate satisfactorily the quality and usefulness of those solutions. There is no convincing evidence that any currently available tests provide a measure of creativity'. Eysenck (1994: 86)[5].

Design

Within Design education there is an assumption - rightly - which assumes concepts such as creativity are of the highest value. Teaching in Design education generally focuses upon the studio system rather than a formal classroom. In studio practise, lecturers do use psychological terms and words to describe directions that the student should be aiming for; these could be creativity, concepts, ideas, personal expression, originality and problem solving. There isn't a consensual definition of some of these terms or how they are represented. The definitions are often based upon the lecturer's knowledge of the terms, which could differ considerably. There is an implicit assumption that the assessor is educated and able to assess creative thinking and knowledge constraints. The personality variables that may contribute to the creative personality are acknowledged, but there are few examples of personality based assessment systems being applied to those involved within design, art, engineering training or education with the exception of psychometrics or the 16 PF Personality Factors assessment system.

There seems to be some differences within the assessment systems when referring to creativity (Kulp & Tarter 1986)[6] refer to 'visually' identifying the students ability, which is appropriate, but the emphasis is upon visual dexterity rather than creativity. Divergent thinking and manipulating shapes may show a different approach to problem solving, even so, how is this creative act? What thought processes have been identified within the assessment? In some ways the assessment is assessing an end product, rather than trying to measure a creative act. Drawing, traditionally, is measuring the fundamental tool for developing an individuals understanding of what is observed, seen and reproduced. These assessments focus upon a small number of variables that may possibly contribute to a definition of creativity within the design domain.

Defining the concept

There are differences in which creativity is perceived in different disciplines; creativity is attributed the highest of values and is associated with the individual being able to produce the 'novel act'. This is - usually - associated with the production of an artefact of some description. Within the context of psychology, creativity as a concept or a 'novel act' is constructed by the corralling of a number of variables that constitute the definition of the term. However, Torrance in the Torrance Test of Creativity (1984)[7] which consists of four categories including fluency, flexibility, originality and elaboration created a system to try and measures creativity. These seemed to be based upon divergent thinking and problem solving skills.

Is it possible to establish variables that may contribute to a conceptual definition and suggest working practises of creativity? If this can be initiated and qualified it may lead to a greater understanding of such an important set of drivers that relate to the sciences and the arts. The following variables have been accrued from academic research, practical experience and colleagues from a wide ranging number of disciplines. Essentially; the variables are defined as academic and working process. The general classes of skills that underpin most conceptions of intelligence; Including, Guilford (1967)[8] structure of the intellect, Earl Hunt's diagnostic assessment incorporating multi intelligences (1983)[9], Gardner's seven intelligence's (1983)[10] and Robert Sternberg's categories of cognitive processes of intelligence [11] (1985) are all acknowledged as seminal texts in the field linked to creativity. Our experiences and observations are acknowledged as part of a personal partonomy of data located in memory which his referred to in the production of ideas when the right perceptual cue is used. Memory is a) semantic and b) long term, episodic and working, Howard (1987)[12]defined the concept as a mental representation of a category, he also and detailed the schema as a mental representation of related categories that established the essential characteristics. Boden (1992)[13] defined it as the, 'semantic net of nodes and links'.

As a principle the subject of creativity and practises are evidenced in many books, documents educational and training programmes; but there are few theoretical or practical definitions of the term offered by educationalists or specialists based upon objective research; rather than personal and subjective opinions. The subject of creativity in engineering, art and design education is embellished with language, terms and concepts which are permeated with theories and 'arts' based associations. This may reflect that the working practises across the disciplines are different and the application of assessment is also different that may measuring different things. This area has been explored by Professor Margaret Boden who has written (1992:20) 'Poincare ascribed a significant mental history. (*to unconscious thought*) Sudden illumination (*is*) a manifest sign of long, unconscious, prior work.' If there is mental activity, could the activity be defined as information via the senses being encoded and categorised to form the basis of memory? How is it possible to quantify 'mental activity' consciously? Boden continues (1992:23) 'The more unusual the association, the more scope there is for truly creative ideas.' The evolution of bisociations of matrices could possibly illuminate the area of the unconscious within the context of creativity. Koestler,[14] states that bisociations different from ordinary association in several ways. The former, in contrast to behaviourism's (though not psychoanalysis) association, achieves its novel combinations via unconscious processes.

Additionally, in the book entitled,' The Nature of Creativity' (R Sternberg 1988) [15] refers to the unconscious and its relationship to creativity. In his essay 'problem solving and creativity' R Weisberg (1988:149/150) refers to creativity when he states, 'unconscious processes, altered states of conscious and remote analysis are three characteristics that have been attributed to creative thinkers.' In the concluding chapter by Sternberg (1988) entitled, 'Integration and conclusions; creating a field of creativity' the authors articulate their equation between thought and creativity.

There are many variations on the working process that are specific to different disciplines. There are many variables in the disciplines of psychology which contribute to the conceptual definition of creativity. There is a natural bias in the following list; the limitations are those of the authors; although, the list is substantial in character. The authors want other that other academics to contribute to the conceptual definition of creativity and the associated working practises. Some of

the working processes concerning the act of being creative, producing ideas and being innovative include the following:

Practise

The individual should be able to encode data: show a refined eclecticism, articulate bifurcating thought, empathise and necessitate associative thought, think thematically, produce unusual juxtaposition of thought and think in 2/3/4/dimensions.The range of skills and abilities should also include the ability to produce novel solutions, formulate & understand concepts, have an awareness of conscious and unconscious thought is not formula lead. But, is also self motivated, disciplined and committed. The individual should establish a partonomy of data, be able to manipulate visual information, include a personal infusion or expression into their work by using the appropriate media and communicate effectively in a visual, oral, and written way. At different points of developing the work the individual should be able to constantly re-evaluate & modify their progress, whilst challenging their own perceptual set. It is a necessity that the students possesses formal knowledge germane to a discipline and be able to produce a perceptual cue and apply logic & serendipity during the process of a creative act. There needs to be an understanding of understanding and knowledge of formal elements of visual history, symbolism, metaphor, analogy, semiotics and semantics. The individual should have the ability to produce primary source imagery, synthesise secondary source imagery, and possess a broad understanding of aesthetics with the ability to overview variables; whilst challenging the perceptual sets of others. Today; it is essential that graduates able to interact with disciplines, be empathetic to 2/3/4/ dimensions whilst being and be able to be sensitive to the difference between object and subjectivity. Ideally, the individual should also have an unrestricted style of working, produce Intra communication work , be able to annotate data, reflect a refined process of evolving & developing work, require information from diverse sources, make decisions, plus produce work in 2/3/ and 4 dimensions.

Thought

Some of the working processes, based upon key areas in psychology in the act of being creative, producing ideas and being innovative include: the ability to produce unprecedented solutions (Torrance 1965),being aware of Poincare's incubation, preparation, illumination and verification as defined by (Boden 1993),exhibiting some form of coherent dynamic as prescribed by G Jung (Abra 1988). The individual should also show a preference for ambiguity (Torrance 1965) and an understanding of the semantic net as explained by (Boden 1992). The individual be open minded to new experiences and exhibit an understanding and empathy with abstract notions, whilst accommodating reflective & reflexivity with the concept of abstraction, (Phares 1984).The individual should have autonomous complexes (H Gardner 1983), be able to comprehend altered states (Earl Hunt 1983); be able to perceive by remote analysis (R Weisberg 1988), understand memory, whether it is episodic, eidetic, procedural, declarative, semantic or working (R Howard 1987).The individual should also exhibit some degree of anxiety / neurosis as defined by Freud /Jung (Abra 1983), Sternberg/ Gardner (1985) emphasised the importance of general intelligence, whilst (Arastek & Arastek 1986) state that sensitivity to the environment, plus being Independent & non conforming are or importance. The individual should also reflect a flexible approach and prefer complex stimuli (Gilchrist 1972), preferably possess informed autonomy, perceptual parameters academic / personal (established) frames of reference, and an awareness of perceptual filtering (Langley/Jones 1984), Ideally there should also be an understanding of concepts, schemata, the interpreter and selector (R Howard 1987). Koestler / Boden (1964 & 1992) state that conceptual foresight is of significance, as is sensing problems (Kulp & Tarter 1986). The ability to resolve problems is of importance,(Sternberg, 1985) as is the application of divergent thought (Earl Hunt, 1983). The ability to form ideas, (Kulp & Tarter 1986) and apply convergent thought (Earl Hunt, 1983) whilst making unusual juxtapositions of elements (Torrance 1965) and searching for alternatives (Sternberg 1985) plus acting affirmatively (Earl Hunt 1983).However, these variables also need to be used within the curriculum at under graduate and level and post graduate studies.

Case Study

Some of these variables have been used in the teaching of the MA programme at Nottingham Trent University. The consideration of these variables provided students with the necessary attributes with which to design make-able, sellable and useful products, it starts with the analysis of needs not taken from a pedagogic perspective but from a metaphysical one. The need of an object, its causation, may be the incubation point for a new approach to product design teaching. Whether

defining a shape or defining the use of a space, invaluable to the student and in sustainable terms the community at large maybe to ask, why do we need this? The desire to create something more than a product should be at the forefront of the design brief; ‘design culture as en-cultured practice may also extend beyond the orchestration of new consumer-producer relation-ships within corporate frameworks, to a process that works to transform every day public lives and aspirations’ (Julier, G. 2008)[16].

Designs both of products and exciting new materials from which they are constructed e.g., memory alloys, still revolve around first principles both in scientific and design methodology terms; but are created through ontological thought process taking into account the nature and style of living most suited for these contemporaneous, changing times.

Figure 1 Examples of designing the use of space resulting in two products.
(MA work produced at Nottingham Trent University 2010)

To usefully create it is necessary to understand the concept of knowledge, the methods of imparting knowledge and to realise the limits of understanding and of what and how we know. The delivery of the curriculum both for design and technology should, it is argued, be heuristic and didactic, teaching by explanation and demonstration rather than a set of rules to follow, as is often the case in structured studies akin to technology. The teaching philosophy should revolve around the interpretation of the metaphysical associations between design and technology; the delivery itself heuristic by operation and epistemic in quality and quantity. Furthermore, it is proposed that the use of specific knowledge which has been imparted through the articulated philosophies will have a synergised benefit both for the individual, be that student or academic, and the community in general. In addition the student experience is enhanced by the process of thinking in abstract terms and erasing ambiguity, preparing them for professional aspirations, careers in industry and commerce or further work leading to research and development activities.

It is argued that elements of the metaphysics of technology, i.e. first principles, often of mechanics and the existence of materials, couples well with design, e.g., physical artefacts produced by conscious thought [causation] being of their own time and space. The result is often objects that need space and designed spaces to exist. Figure 1, shows an elegant water dispenser, requiring space to place the cup and deliver its function, also requiring space to exist, as does the light, made from sheet material of organic light emitting diodes, it is both light and shade, using space efficiently, made from three metres of material but finished only one metre in length spacing space but utilising it for its function and form.

Conclusion

Mechanical Engineer designers have to be catalysts for change simply because it is the way in which the global market place is developing today. In the Times Higher Educational Supplement (Dyson, 2010 :28-29)[17] James Dyson stated, 'science and engineering (*are*) emerging from a long era of neglect' and continued to make several statements that should be considered,' Inspiration and greater investment are the real mothers of invention' supported by,' research and ideas that come out of universities are vital to our economy' and re – enforced the importance of approaching research in different ways by saying, 'blue sky research projects keep genuine breakthrough alive'.

Measurements are available to assess creativity, but are inclined to be rooted in subjectivity. There are objective systems, but, they seem to be based upon psychometrics and competencies. There is a need to separate the intangible and the tangible variables and correlate them into a coherent instrument of assessment, which allows an articulate approach to complex problems and allows us to measure the value of the ideas that are produced. Indeed, we are certain that there are many important variables can contribute to our – loosely - based definition.

This paper is original in its inception and content. The contributors work in engineering, design, science and art arenas; all of whom share a joint focus in trying to establish a greater definition of the concept of creativity across the disciplines to synchronize theory and practise to reflect current developments in research and business practise. The variables that have been suggested are a starting point to consider when defining the concept and working practises of creativity and innovation. The variables emanate from the disciplines of design, engineering, psychology and art. This cross discipline approach is a fertile ground for diverse approaches and applications to the production of concepts and ideas. The working processes referred to in this paper do have limitations, but it up to us - collectively – to try and extend these practises, so they are inclusive where necessary, but, ultimately facilitate the production of products by engineering designers.

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