Journal of Engineering Education, April 2009 by CHRISTINE CHARYTON, JOHN A. MERRILL

Summary:

Creativity is a vital tool for innovation in engineering. Psychology and engineering faculty developed the Creative Engineering Design Assessment (CEDA) because existing tools are limited. This measure was administered with general creativity measures in 63 engineering (57 males, six females) and 21 non-engineering (six males, 15 females) students in five week intervals. Inter-rater reliability showed high consistency overall and between the test and retest administrations. Only engineering males and females significantly differed on the retest. Engineering students with low, medium, and high creative engineering design did not statistically differ in their general creativity, not domain specific to engineering; however, only high scorers were significantly higher on the retest from the other groups. Future research is needed with larger samples.ABSTRACT FROM AUTHOR

Excerpt from Article:

Assessing General Creativity and Creative Engineering Design in First Year Engineering Students

CHRISTINE CHARYTON
Department of Psychology Ohio State University person, and the production of something new to an individual or culture. Creativity has been explored in relation to process, product, personality, and press or environment (Sternberg, 1999; Sternberg and Dess, 2001). Central themes specific to engineering creativity include novelty and usefulness (Larson, Thomas, and Leviness, 1999; Nickerson, 1999; Thompson and Lordan, 1999). Engineering is an applied science where diagnostic procedures and problemsolutions are derived (Schon, 1983). Innovation is a process to place new ideas into practice where creativity acts as a vital tool (Thompson and Lordan, 1999). This study builds upon the current creativity research in psychology and engineering education. The research project goals are to provide a useful tool that can effectively assess creative engineering design at the university level in engineering education. A. Practicality of Creativity More recently, creativity has received greater attention as a necessity, rather than an accessory in engineering design. "Creativity is important to society, but it traditionally has been one of psychology's orphans" (Sternberg, 1999, p. 4). Even within psychology, creativity has often been neglected. Czikszentmihalyi (1999) suggested that the person, domain, and field are relevant to understanding creativity and innovation. Problem posing has been emphasized by the minds of many disciplines in art and science (Smilansky and Halberstadt, 1986). Highly creative people redefine problems, analyze ideas, persuade others and make reasonable risks to help generate ideas (Sternberg and Dess, 2001). "Creativity is certainly among the most important and pervasive of all human activities. Homes and offices are filled with furniture, appliances, and other conveniences that are products of human inventiveness" (Simonton, 2000, p. 151). Engineering is a creative profession that may be misunderstood. The ability to measure creativity would not only facilitate the identification of talented individuals, but also would allow the measurement of baseline information necessary to track the progress of educational and training programs aimed at enhancing creativity (Treffinger, 2003). "The need for people skilled in helping others use creative problem solving is increasing" (Isaksen, 1983, p. 18). This need is evident in both engineering and the practice of psychology. B. Engineering Creativity "Creativity, **problem solving**, and innovation are of increasing concern to organizations in these times of accelerating change" (Basadur and Finkbeiner, 1985, p. 37). The need for creativity, problem solving, and innovation is becoming a global need. A growing interest in the need and utilization of creativity in engineering design is evident. Shirley interviewed by Elliott stated, Journal of Engineering Education 145

JOHN A. MERRILL
College of Engineering Ohio State University

ABSTRACT

Creativity is a vital tool for innovation in engineering. Psychology and engineering faculty developed the Creative Engineering Design Assessment (CEDA) because existing tools are limited. This measure was administered with general creativity measures in 63 engineering (57 males, six females) and 21 non-engineering (six males, 15 females) students in five week intervals. Inter-rater reliability showed high consistency overall and between the test and retest administrations. Only engineering males and females significantly differed on the retest. Engineering students with low, medium, and high creative engineering design did not statistically differ in their general creativity, not domain specific to engineering; however, only high scorers were significantly higher on the retest from the other groups. Future research is needed with larger samples. Keywords: creativity, engineering design, innovation

I. INTRODUCTION

Creativity research in engineering began to blossom in the 1950s (Ferguson, 1992). The recommendations of **Vannevar Bush**, an electrical engineer from MIT, led to the establishment of the National Science Foundation in 1950. In the early 1960s, the National Science Foundation sponsored conferences on "scientific creativity." Yet, "as interest in engineering design faded in most engineering schools, creativity was put on a back burner" (Ferguson, 1992, p. 57). Many engineering education programs appreciate and value creativity, but few offer courses that teach about creativity. Creativity is defined as a preference for thinking in novel ways and the ability to produce work that is novel and appropriate (Sternberg, 1999; Weisberg, 1986) (see also Charyton, 2005). This type of creativity can also be defined as "general creativity" that is not domain specific (Charyton, 2005; Charyton and Snelbecker, 2007). Torrance (1974) stated that creativity has been formulated in terms of a product (invention and discovery), process, a type of April 2009

"I think if engineers are not creative, they're not engineers" (Elliott, 2001, p. 22). How can an engineer be effective without creativity? Designers have been engaged for centuries in engineering design; however, only in the past few decades has there been a systematic process capable of comprehensive analysis and improvement (Soibelman and Pena-Mora, 2000). The need to assess and enhance creativity in engineering design is evident in many university programs. There is a crucial need to teach about "real-world" engineering design and operations that call for critical judgment and creativity (Felder et al., 2000, p. 26). Creativity education is critical in engineering education as well as general education (Ishii and Miwa, 2005). Psychology is helpful to address creativity in education by promoting learning through meta-cognition and self reflective activities (Ishii and Miwa, 2005). Students can gain confidence to exercise reflection-in-action with a supportive learning environment that does not hinder their creativity (Green and Kennedy, 2001). Stimulating activities can encourage creativity and innovation. Through incorporating knowledge from psychology into engineering education, students can experience creative activities, reflection, and their own awareness of their cognitive processes (Ishii et al., 2006). In the past, educational psychologists have assisted engineering education faculty with enhancing learning for engineering students (Felder, 1998). Empirical studies in educational and cognitive psychology literature address methods for learning. These methods have been implemented successively in engineering classes. Realworld applications, cooperative learning, active learning, deductive, and inductive learning are important for developing creativity. Reflection-in-action is learning by doing (Schon, 1983). Students also need to practice skills before they are assessed. Furthermore, experiential learning provides students with opportunities to select assignments and promotes deeper learning. The goals and objectives in engineering education need to be defined, clear and measurable (Felder and Brent, 2003). Creative engineers are needed to solve technological problems. "It would seem to be our responsibility to produce some creative engineers-- or at least not to extinguish the creative spark in our students" (Felder, 1987, p. 222). Is it possible that engineering education decreases creativity and originality? To develop and nurture critical and creative problem solving skills, we must provide opportunities for students to exercise these skills. Open-ended questions, problem finding, fluency (quantity of solutions), flexibility (variety of solutions), and originality (novelty) are vital components toward enhancing analysis and synthesis of information learned (Felder, 1987; Isaksen and Parnes, 1985). Shah, Smith, and VargasHernandez (2003) also describe these three constructs (fluency, flexibility, and originality) under different terms such as quantity (total number of ideas generated) variety (areas of the solution space), and quality (feasibility of an idea to meet the design specifications). According to Shah et al., novelty is an approach to measure effectiveness that relates to quality. Central themes specific to engineering creativity include originality (novelty) (Shah, Smith, and Vargas-Hernandez, 2003; Thompson and Lordan, 1999; Weisberg, 1999) and usefulness (applicability) (Larson, Thomas, and Leviness, 1999; Shah, Smith, and Vargas-Hernandez, 2003; Thompson and Lordan, 1999). Engineers not only need to address aesthetics like artists, but also need to solve problems, prevent potential problems, and address utility within the constraints and parameters that are designated. 146 Journal of Engineering Education

Furthermore, creativity as an aspect of engineering can be referred to as "functional creativity" (Cropley and Cropley, 2005). Functional creativity means that products designed by engineers typically serve a functional and useful purpose, unlike fine art. Creative products emphasize novelty, resolution, elaboration, and synthesis (Cropley and Cropley, 2005). Furthermore, problem finding may offer another avenue to increase creative production (Nickerson, 1999). Problem finding is a skill often found in art, yet is also necessary in science and engineering. Both problem finding and problem solving are relevant to an engineer's creativity; however, these attributes have not been measured in great depth in engineering creativity specifically. Such attributes need to be assessed and further developed by appropriate educational intervention activities (Cropley and Cropley, 2005). The need to measure these attributes in individuals and teams would be appropriate and beneficial. Measuring creativity in engineering design is necessary to assess how these skills are demonstrated and developed in engineering programs. Engineering students may profit by understanding constraints through reflective learning that are necessary to be creative in the engineering field. Students may also become aware of their own meta-cognitive processes to enhance their skills in engineering design (Ishii and Miwa, 2005; Ishii et al., 2006). Charyton (2005) and Charyton and Snelbecker (2007) investigated measures to assess creativity in engineering students. Like the work of Basadur and Finkbeiner (1985), Charyton and Snelbecker (2007) explored much of the literature in creativity assessment and consulted psychologists and engineers assessing creativity. Conclusions indicated that measures such as the Myers Briggs Type Indicator (MBTI) did not specifically address creativity in engineering or engineering design. The MBTI has limitations and does not specifically assess creativity (Larson, Thomas, and Leviness, 1999). To date, existing engineering creativity measures are limited. According to the literature available, there are few measures to assess creative abilities in engineering design. The Owens Creativity Test (Owens, 1960) was developed to assess mechanical engineering design. Test takers list possible solutions to mechanical problems. Its reliability ranged from 0.38 to 0.91 and its validity ranged from 0.60 to 0.72, when applied to engineers in mechanically related occupations. This assessment tool is out of print and is no longer used. Lawshe and Harris (1960) developed the Purdue Creativity Test as an engineering personnel test, for identifying creative engineers and their occupational potential. Participants are instructed to list as many possible uses for one or two shapes that are provided. This assessment has adequate reliability (0.86 to 0.95) and modest validity (29 percent to 73 percent for low scorers and high scorers, respectively). Validity was determined by assessing professional engineers (product, process, and product engineers) working in industry. Participants are instructed to generate original and novel possible uses for single objects or pairs of objects. Scoring is based on fluency (number of uses), and flexibility (differing categories of uses). Their test does not directly assess originality. Although a reliable and valid measure, limitations include little use in the field of engineering. This assessment measures engineering creativity by assessing fluency (number of responses) and flexibility (categories of responses). Both the Owens Test and the Purdue Creativity Test only measure **divergent thinking**. Traditional divergent tests (e.g., the Purdue Creativity Test, and the Owens Creativity Test) only measure lists of possible uses. The April 2009

Creative Engineering Design Assessment (CEDA) offers a new method for assessing creative engineering design. Participants are asked to sketch designs that incorporate one or several threedimensional objects, list potential users (people), and perform problem finding (generate alternative uses for their design) as well as problem solving in response to specific functional goals. Sketching is instrumental in design problem solving (Goldschmidt and Smolkov, 2006) and results in creative solutions. Sketching is useful for more creative results due to experience for spatial manipulations that are domain specific. Design is crucial for creativity and innovation for users and customers (Cockton, 2008). Engineering creativity involves both convergent and divergent thinking. The CEDA measures both convergent (generating a solution to the problem posed) and divergent thinking (generating multiple solutions to problems posed). Constraint satisfaction is assessed by measuring the amount of shapes used as well as the materials added to each design. Schon (1983) also reported that Schein segregates convergent science from divergent practice. Furthermore, Schein relegated divergence to a residual category as a skill that is present in minor professions, compared to convergence in major professions. He stated that major professions include medicine and engineering while other professions, such as education and social science are attracted by the major professions as models. The study of creativity in psychology has traditionally emphasized divergent thinking skills (Torrance, 1974; Guilford, 1984). In the CEDA model, convergent science and divergent practices are integrated as necessary functions of cognitive processes that are assessed for creative engineering design. The CEDA measures constructs that are a part of the design process as a step by step process, beginning with sketching a design for each problem. Figure 1 shows the theoretical rationale of con-

structs necessary for the creative design process and for the selection of instruments to assess creativity in engineering design. This figure is based on previous studies to assess creativity as defined by the person, process, product, and environment (Clapham, 2001; Sternberg, 1999) and conceptualization of necessary creative processes in engineering design (Cropley and Cropley, 2005; Finke, Ward, and Smith, 1992; Stokes, 2006) that are domain specific (Kaufman and Baer, 2005; Nickerson, 1999). Problem finding, problem solving, divergent thinking, **convergent thinking**, and constraint satisfaction are necessary in the creative process of engineering design (see also Charyton, Jagacinski, and Merrill, 2008). Our model, depicted in Figure 1 illustrates that personal attributes of the individual defined as personality, temperament, and cognitive risk tolerance influence one's creative process. The environment of the individual, defined as the engineering classroom or industrial setting, also influences the creative process. The creative process is defined as using divergent thinking, convergent thinking, constraint satisfaction, problem solving, and problem finding to create a design. The creative process directly affects the product design. At the same time, the product design dialectically influences the creative process. The product is shaped through the creative process. At the same time, product development influences the creative process. Last, the CEDA is a measure of the product design that is developed by the creative process. Each portion of each problem directly relates to psychological constructs of engineering creativity that are described from the literature. Figure 2 describes the theoretical rationale for the test construction of the CEDA, based on creativity literature specific to engineering creativity shown in Figure 1. Figure 2 shows how each item on the CEDA addresses these theoretical constructs. Divergent thinking is assessed by generating multiple solutions. Convergent

Figure 1. Conceptualization of measures addressing creative mechanisms in engineering design (Charyton, Jagacinski, and Merrill, 2008). April 2009 Journal of Engineering Education 147

Figure 2. Creative engineering design assessment meta-cognitive processes measured. thinking is assessed by solving the problem posed. Constraint satisfaction is assessed by complying with the parameters of the directions and also adding additional materials and manipulating the objects as desired. Problem finding is assessed by identifying other uses for the design. Problem solving is assessed by deriving a novel design to solve the problem posed. The readability and comprehension of the CEDA is appropriate for college students. The Simple Measure of Gobbledygook (SMOG) (McLaughlin, 1969) online program was used to assess the reading and comprehension level of the CEDA, using established readability formulas, available at: http://www.harrymclaughlin.com/SMOG.htm. This formula provides the widest range of educational level and ability …