THE IMPACT OF USING A MULTIMEDIA LEARNING TOOL ON MECHANICAL ENGINEERING STUDENTS' CREATIVITY

Submitted by

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List of Abbreviations

ACL	: Adjective Check List
ANCOVA	: One-way analysis of covàriance
ANOVA	: One-way analysis of variance
APA	: American Psychological Association
CLT	: Cognitive Load Theory
CPSS	: Creative Product Semantic Scale
CTML	: Cognitive Theory of Multimedia Learning
EAC	: Engineering Accreditation Council
ILS	: Index of Learning Styles
IPAR	: Institute of Personality Assessment and Research
MANOVA	: Multivariate analysis of variance
MLT	: Multimedia Learning Tool
MMPI	: Minnesota Multiphasic Personality Inventory
SOI	: Structure-of-Intellect
TTCT	: Torrance Tests of Creative Thinking

Abstract

This research examines the impact of utilising multimedia learning tool (MLT) on engineering students' ability to think creatively and make creative engineering products. This research links multimedia learning to creativity by looking at how to manage cognitive load on the cognitive system for effective information processing and knowledge construction. Theoretical perspectives include Cognitive Load Theory (Sweller et al., 1998), Cognitive Theories of Multimedia Learning (Mayer, 2009) and creativity theories (Runco & Chand, 1995; Wallas, 1926). The influences of moderating variables such as students' diversity, environmental factors and emotional effects were also explored.

This research used a mixed method approach with a pre-test post-test quasi-experimental design as the predominant data gathering method. The Torrance Tests for Creative Thinking (TTCT) and the Creative Product Semantic Scale (CPSS) were used. This study extends previous research by including in its outcomes, the use of established creative performance measurements. Other research instruments used included a student questionnaire, observation and semi-structured interviews.

Based on a successful outcome in a pilot study, the main study tested the assumption that using MLT would assist engineering students to perform better in their understanding and creative performance. Results from the interviews and student questionnaire supported the assumption, as did the analysis of the other test scores. Differences in mean scores showed that students who used the MLT performed better creatively than students who did not. However, the main statistical analyses of creative thinking and product creativity did not reach significance.

A key innovation in this study was that unlike previous studies in multimedia learning and cognitive load that have been conducted in controlled lab-based

conditions, this study was conducted in actual classroom environments. As a result of examining these environments, this study has identified the effects of two new loads on the cognitive process: the environmental and emotional loads. Both loads appear to have increased the extraneous cognitive load and impeded the cognitive process for learning and creative performance. This study also looked at the influence of students' diversity in terms of learning styles, level of confidence in their knowledge and self-perception of their creative abilities on the main relationship between the use of the MLT and its effects on students' creativity. The findings indicate that the MLT is most advantageous for students with high preference for visual learning materials, lower confidence in their knowledge and high self-perception of their creative abilities.

Based on the findings, *a four-phase recursive model of the creative process* has been proposed to explain the creative cognitive process. This model takes into account the architecture of human cognition, cognitive load and the moderating influences on creative outcomes.

Chapter One: Introduction

1.1 Preamble

In a world where technology is a widespread necessity, computer technology is becoming a powerful tool of change in education (Warschauer & Ware, 2008). One type of computer technology that is applied extensively at all levels of education is multimedia technology (Giller & Barker, 2006). Multimedia technology can be used to develop learning materials that have an interactive and animated interface, especially where information is presented using audio and computer graphics. Studies of the effectiveness of learning materials and learning programs that use multimedia technology have been conducted for decades (Issing, 1994; Mayer, 2009). The use of multimedia technology for learning needs to be based on understanding how this technology can best be exploited to benefit students (Mayer, 2009). This understanding should include how to effectively design the learning materials to accommodate learners' cognitive system, learning environments and their individual differences (Mayer, 2009; Sweller, van Merrienboer, & Paas, 1998; Warschauer & Ware, 2008).

This research focuses on the impact of multimedia learning materials on students' creativity. The trial of the learning materials was conducted in an actual classroom environment. The influences of individual differences such as learning styles, confidence in knowledge and self-perception of creative abilities were examined as moderating variables. This study adds to previous research on multimedia learning and cognitive load by opening up the possibilities of examining environmental influences on learners' cognitive processes and creative performance. Potential influences therefore include environmental factors as well as the influencing factors that may result from students' work in actual classroom environments.

1.2 Overview of the Thesis

This thesis is organised into seven chapters. The first chapter offers an overview of the educational, empirical and theoretical concerns related to the research problem. The educational concerns arise out of the need to address the acquisition of creativity-

related skills for engineering students and of using computer technology within the educational context. Theoretical concerns are explored in order to understand the principles for effective design of multimedia learning materials for improved creativity-related skills. Empirical concerns are related to the importance of conducting this research in actual classroom environments, which previous studies lack. The influences of student diversity and factors from the environment on students' cognitive processing and use of multimedia learning materials are important in order to understand their impact on creativity. These issues will be reported in Chapter One. The detailed discussion that sets up the framework for the research will review the current literature and this study's argument will be presented in Chapters Two and Three. Chapter Three also describes the development of a multimedia learning tool (MLT), which is the main material for this study. A CD, which contains 37 multimedia clips of the MLT, is also included with this thesis.

The methodological considerations are explained in Chapter Four. These include the description of all the research instruments used in this study, the reliability and validity estimates of the instruments, and research design for both the pilot and main studies. Chapter Five reports on the findings of the study using both quantitative and qualitative analyses, and Chapter Six discusses and interprets the findings. Finally, Chapter Seven summarises the study, describes its theoretical and practical implications and provides suggestions for future research.

1.3 Background to the Research

The ubiquity of technological advancement, the rapid expansion of information, and the widespread practice of collaboration between different fields of studies such as engineering and social sciences have increased the demand for individuals and workers who are highly skilled and knowledgeable. Through this lens, creativity is seen as one of the essential skills that can be a factor for individual survival (Amabile, 1996) as well as organisational survival (Dhillon, 2006). 'Practical ingenuity and creativity' is one of the five necessary skills which the next-generation engineers need to possess (Bengelink, 2007). As Runco (2004a) stated, individuals with creative personalities possess flexibilities in their characters that enable them to cope with changes and

difficulties in order to seize the opportunities in the fast-moving society that we live in today.

Studies of creativity have indicated that creativity can be fostered and learnt through technology manipulation, specifically through learning and teaching materials (Cropley, 2001; Cropley & Cropley, 2008). Despite the effort made to provide highly technological advantages to educational communities, the question that needs to be asked is whether this technology can be engineered and utilised as learning tools in order to develop creative potential. Therefore, the present study aims to explore whether providing engineering students with multimedia learning materials can improve or enhance their creativity.

1.4 Educational Concerns Related to the Problem

1.4.1 Impact of Globalisation on Malaysia's Education System

In Malaysia, the impact of globalisation was illustrated by the government's concerted effort to move the country towards a knowledge-based economy (K-economy) in the 1990s. This was steered by an ICT-driven infrastructure and the development of a knowledge-based society (Vicziany & Puteh, 2004) to help transform Malaysia into a developed nation (Awang, 2004). Beginning in 1995, the Malaysian education system was transformed, and over the next 15 years, educational reform characterised school curricula and tertiary education (Kamogawa, 2003). At the higher education level, the National Higher Education Strategic Plan was laid down in 2007. The strategies that were implemented were directed towards educational transformation that included the introduction of science and technology courses at private universities, the establishment of six new engineering-based public universities, funding for the development and improvement of ICT infrastructure for teaching and learning purposes and emphasis on teaching and learning methods to promote creativity, innovation and thinking skills (Economic Planning Unit, 2001b; Kamogawa, 2003; Ministry of Higher Education, 2007).

The emphasis given to engineering courses is evident with the steady increase in the number of student enrolments and graduates in recent years compared to the 1990s. The Economic Planning Unit of the Prime Minister's Department, Malaysia (2001a)

documented that there was a steady growth in the percentage of engineering graduates in the late 1990s. Recent statistics by the Ministry of Higher Education (2009) also showed a constant growth in the enrolment and graduate percentages for engineering courses in public educational institutions. As a result, six public engineering-based universities were established to cater for this demand. One of the challenges for each of these newly-established engineering-based universities is to ensure that the graduates are creative because creativity is regarded by employers as one of the skills that engineering graduates need to possess (Sns Bukhari, 2005; Zakaria, Che Munaaim, & Iqbal Khan, 2006).

1.4.2 Emphasis on Creativity in Engineering Curriculum

The Engineering Accreditation Council (EAC) of Malaysia, a body responsible for the accreditation of the engineering programs at Malaysian educational institutions, listed 10 generic attributes of an engineer from the employers' perspective. One of these generic attributes is adaptability through creative thinking and problem-solving skills (Sns Bukhari, 2005). In addition, the Malaysian Employers Federation (2004) reported that one of the criteria adopted by employers during recruitment is the potential employee's ability to generate creative ideas. Zakaria et al. (2006) also stated that within the field of civil engineering, creativity emerged as one of the demanded soft skills. Tengku Tan Sri Mahaleel Tengku Arif, the former Chief Executive Officer of Proton Holdings Berhad, Malaysia's first national car company, provided a synthesis of qualities that engineering employers expected from their engineering graduates. These qualities are presented in Table 1.1 (taken from Zakaria, et al., 2006), which indicates that creativity is a necessary attribute sought by engineering employers, with the implication that creativity needs to be given emphasis in engineering curricula.

Table 1.1. Qualities of an Engineer Required by Employers

Skills	Qualities
Hard Skills	Mathematics, Technologies, Business and Economic, Human Resource, Science, IT Skills, Global Politics, Global General Knowledge, Geography, Coaching Skills
Soft Skills	Creativity, Innovative, Multilingual, Communication Skills, Analytical and Critical Thinking Skills, Helicopter View, Leadership Skills
Competitive Skills	Drive for results, Can do attitude, Attention to details, Teamwork, Consensus

1.4.3 Scarcity of Creativity Studies in Asia

Studies of creativity in the Western world especially in the U.S. and the U.K. have been conducted for decades (Runco & Albert, 2010). A significant increase in creativity research began following Guildford's (1950) presidential address at the American Psychological Association (APA). What began as an interest in intelligence (Guildford, 1975) has proliferated into diverse areas of interest which include cognition, personality, motivation and more recently the alignment with developing technology. In Asia, however, creativity research is still emerging as a field.

Even though the number is still very small, studies on creativity in Malaysia are increasing. Some of the earliest studies of creativity conducted in Malaysia were carried out by Yong (1987, 1989) and Palaniappan (1989, 1994). These studies focused on identifying school children's creativity and its relationship to academic achievement. More studies examined the creativity of school pupils (Abd Hamid, 2008; Malayalam, 1998), tertiary students (Chua, 2002; Lee, 2005) and employees (Ow, 2009). These studies mainly explored creativity within the area of arts and language (Chua, 2002; Lee, 2005), mathematics (Idris, 2006), and its correlation with other creativity-related variables such as critical thinking (Chua, 2002). No educational studies, thus far, have been found that examine creativity within an engineering context at the tertiary level in Malaysia.

Educational studies which investigated the effects of computer utilisation or development of multimedia learning software did not examine the effects of the technology on creativity (Saleh, 2006; Tang, 2007). Studies which looked at the effects of technology on creativity within educational contexts are limited to general computer use (Idris & Mohd Nor, 2010; Malayalam, 1998). Consequently, more studies that can contribute to the literature of creativity in Malaysian context need to be conducted especially within the engineering context and at the tertiary level.

In a slightly larger context, the literature on creativity studies in Asian countries, namely Singapore, South Korea, Japan, Hong Kong and Taiwan, is greater than in Malaysia. Kim (2005) dubbed these countries the East Asian Five Dragons due to their rapid economic growth. One of the interests in creativity studies in these countries is to

examine whether economic growth is attributable to people's culturally embedded characteristics such as being hardworking. Creativity research in Singapore includes conceptual analysis and empirical experimentation displaying a focus on different disciplines of studies and at different educational levels (Tan, 2000). This was particularly due to Singapore's rapid development and technological advancement (Tan, 2000, 2004). This indicated that the growth of interests in creativity research in Asia can largely be attributed to economic growth and technological development.

1.4.4 Impact of Technology on Learning Materials

Technology allows for easy access to abundant information in a variety of delivery media such as the Internet. Technology also allows the presentation of information in many different ways (Mayer, 2009; Rouet, 2001), for example, presentation of static graphics and texts using *PowerPoint* or animation and audio using *Flash* or *Media Player*. Computer technology can be employed to transform texts and graphics and manipulate colours, audio or other computer effects to create more dynamic and animated representations of information. Representations of information can therefore be transformed from static and paper-based formats into dynamic representations (Giller & Barker, 2006; Rouet, 2001). This allows for new tools, materials and techniques to be used in teaching and learning processes.

Multimedia learning is a research area which investigates the effectiveness of learning materials that use multiple information representations. Basically, multimedia learning refers to learning using materials or tools which consist of a combination of words and pictures (Mayer, 2001, 2009). Mayer (2001, 2009) did not specify how the learning materials should be presented; any type of learning materials which contains words (as printed text or narration) and pictures (as static graphic or dynamic animation) is considered multimedia learning materials. Therefore, print-based materials such as textbooks, technology-based materials such as videos and computer-based materials such as *PowerPoint* and multimedia presentations which utilise both words and pictures are examples of multimedia learning materials. In the context of this study, however, multimedia learning materials are defined as multiple information representations in the learning materials, and the development of these learning materials to make use of multimedia technology. In Malaysia, the use of static and paper-based learning tools is

still the preferred method, but the use of multimedia learning materials is increasing, especially Internet, computer and multimedia technologies (Teoh & Neo, 2006). It is the aim of the present study to examine the influence on creativity of learning tools which are developed using computer technologies.

1.5 Empirical and Theoretical Concerns Related to the Problem

1.5.1 Fragmented Research on Creativity

Creativity is a multi-faceted construct (Isaksen, 1987; Rhodes, 1961) and its complex nature makes it a complex construct to define and examine. For this reason, creativity researchers and theorists have defined creativity based on their respective world views, paradigms, and methodological orientations. Rhodes (1961) was one of the early creativity researchers who examined creativity in an attempt to provide a single definition of creativity. He defined creativity as "a noun naming the phenomenon in which a person communicates a new concept. Mental activity is implicit in the definition, ..., so the term press is also implicit" (Rhodes, 1961, p.305). His definition divided creativity into four mutually overlapping and intertwined dimensions, which are person, process, press and product. Person deals with traits and personalities of creative individuals, process looks mostly into the cognitive process which leads to creativity, press looks at the influences of environmental factors that can promote and hinder creativity, and finally product indicates the characteristics of creative products. This categorisation has been widely accepted as the dimensions of creativity, and is known as the 4Ps of creativity.

Creativity research has become fragmented by this categorisation (Barron & Harrington, 1981; Kozbelt, Beghetto, & Runco, 2010; Runco, 2004a). Prior to the 1980s and due to the influence of Guildford's (1950) presidential speech at the APA, focus on creativity research was on the person and process dimensions. In fact, the most researched of the four dimensions are person and process (Barron & Harrington, 1981; Runco, 2004a). However, in order to better understand creativity, all four dimensions needs to be considered and investigated as one systematic construct and not in fragments (Mumford, 2003; Rhodes, 1961). Recent creativity research and theories have employed a convergent approach to the understanding and examination of creativity (Kozbelt, et al., 2010). Through this approach, all the 4Ps of creativity are being

investigated although the emphasis on particular dimensions might not be equal. The present study therefore attempts to examine all four creativity dimensions; the main focus will be on process and product dimensions while press and person dimensions will be examined as moderating variables.

1.5.2 The Importance of Knowledge for Creativity

Guildford (1975), Sternberg (2006b), Torrance (1965) and other major researchers posited that knowledge is one of the essential elements needed for creativity. The depth of one's knowledge in one particular domain as well as the extent of general knowledge can help a person to generate creative ideas. Studies on eminent creative individuals such as Mozart postulated that deep knowledge of their domains is one of the factors that facilitated these individuals' creative achievements (Csikszentmihalyi, 1996; Simonton, 2010). With a deeper knowledge base, the association of information and knowledge across remote and divergent ideas can lead to creativity (Guildford, 1975; Mednick, 1962).

Moreover, creativity can be learnt and fostered, and one of the ways to foster creativity in the classroom is by changing the learning and teaching materials (Cropley, 2001). Therefore, providing students with learning materials that ease the process of acquiring information and constructing knowledge may assist in enhancing students' creativity. Research in multimedia learning has proven that multimedia learning materials can help students acquire information and construct knowledge (Mayer, 2009). This study therefore seeks to discover whether using multimedia learning materials as a tool for knowledge construction helps students perform better creatively.

1.5.3 Multimedia Learning Materials and Creativity

Research in multimedia learning investigates how multimedia learning materials should be designed in order to accommodate the systems and processes of human cognition (Mayer, 2009). The architecture of human cognition consists of sensory memory, working memory and long-term memory. All active processing of information occurs in working memory, which is limited in its capacity and duration (Baddeley, Eysenck, & Anderson, 2009; Sweller, et al., 1998). By employing Cognitive Load Theory (Sweller, et al., 1998), multimedia learning research considers the

cognitive load on working memory in the design of multimedia learning materials. When load on working memory can be managed and reduced, working memory's processing capacity increases. This can lead to information acquisition, knowledge construction and eventually meaningful learning (Mayer, 2009; Sweller, et al., 1998). Mayer (2009) defined meaningful learning as students' ability to utilise in novel ways the information presented in multimedia learning materials. Hence, this study aims to examine the appropriate design of multimedia learning materials that can be used to enhance students' creativity.

Participants in multimedia learning studies have so far been tested only on retention and transfer performance tests (Ayres & Paas, 2007; Mayer, 2009; Seufert & Brunken, 2006). Although Mayer (2009) defined performance in transfer tests as students' ability to utilise their knowledge in a new situation or to solve problems in novel ways, he did not specifically define creativity. Furthermore, the content of the transfer tests was related to the content of the multimedia learning materials. To date, there are no multimedia learning studies which have used established creativity measurement instruments. The present study therefore attempts to measure the effectiveness of using multimedia learning materials on students' creative performance by using established creativity measurements such as the Torrance Tests of Creative Thinking (TTCT) and the Creative Product Semantic Scale (CPSS).

1.5.4 Multimedia Learning Studies in Actual Classroom Environments

Research in multimedia learning has been conducted for over three decades. However, most studies have been carried out in laboratories under experimental conditions (Mayer, 2009). Within this setting, participants were timed for all their activities, and performance measurements were administered immediately after they used the learning materials (Harp & Mayer, 1997; Leahy, Chandler, & Sweller, 2003; Mayer, 2009; Mayer & Chandler, 2001; Moreno & Mayer, 1999; Tindall-Ford, Chandler, & Sweller, 1997). The effects of using the multimedia learning materials on students' mental loads, and learning and creative performance were therefore constrained within the conditions of the laboratory settings, and the controlled experimental conditions.

Creativity is a complex phenomenon (Isaksen, 1987; Rhodes, 1961) which requires time for growth and appropriate environments in order to nurture its development (Martindale, 1989; Simonton, 2004). Thus, in order to better understand how the multimedia learning materials could help in enhancing students' creativity, administering the study in actual classroom environments could provide a better avenue for exploring creativity development.

Conducting the study in actual classroom environments could also assist in identifying environmental influences that could affect the learning process. Environmental factors such as the classroom settings, the general atmosphere of the learning environment, group interactions, and time spent studying the learning materials as well as feelings and moods which might be aroused by the environmental factors can affect the learning process and creativity development. Research on memory has shown that environments and emotions produced from interactions with such environments can affect the cognitive process (Baddeley, et al., 2009). This study therefore attempts to explore the effectiveness of a multimedia learning tool (MLT) on students' learning and creativity by conducting it in actual learning environments.

1.6 Statement of the Research Problem

Studies that examine the effectiveness of multimedia learning materials in actual classroom environments on students' learning and creativity are still lacking. Hence, the present study attempts to examine the use of multimedia technology in the design of the MLT and the application of Mayer's (2002, 2009) Cognitive Theory of Multimedia Learning's design principles. Mayer (2009) proposes twelve design principles with the objective of managing different types of cognitive load, i.e. extraneous, intrinsic and germane cognitive loads, in order to achieve meaningful learning. This study applies multiple design principles to develop the MLT, and the use of the MLT by engineering students in their actual classroom environment in Malaysia. This study contributes to the literature on multimedia learning from the perspective of its effects on creativity and environmental influences on cognitive load and cognitive process.