DEVELOPMENT OF CREATIVE THINKING SKILLS MODULE FOR ENGINEERING DESIGN PROCESS

CHUA YAW LONG

UNIVERSITI PENDIDIKAN SULTAN IDRIS

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RECOGNITION

The quest for knowledge is not a destination but rather a very meaningful journey for me. This journey would not be completed with the help and support from many.

Sincere appreciation to my respected supervisor Associate Professor Dr. Balamuralithara who had provided his guidance and support throughout my journey in this quest for knowledge. I assure you that my journey would not end here and would carry on this quest for knowledge.

To my late wife, Wong Soo Yee: I finally accomplished what we set out to do. My vow to you is what drives me to continue this journey despite the various challenges, falls and attempts. Getting up each time after the fall is hard but with your love and care that remain secured for eternity in my heart, I am able to rise time and again.

To my wife, Foo See Leng, thank you so much for picking me up and being there for me throughout the journey. This journey with you is definitely worth the fight. Couldn't have done it without you.

To my parents, Chua Tian Hock and Ng Yoke Mooi, I hope my achievement has made both of you proud. To my siblings, thank you for the support and kind wishes.

Last but not least, to my mentor in life, Dr. Daisaku Ikeda, thank you for all the guidance that you share with your life experience.

ABSTRACT

The objective of this study was to design and develop a creative thinking skills module for engineering design process at tertiary level. The study also aimed to evaluate the effectiveness of the developed module in improving the creative ability of the engineering undergraduates. The module was developed using the ADDIE instructional design model. Mixed method was utilised during the evaluation phase at the studied university. The participants were recruited from third year engineering students enrolled in an advanced engineering design related module. Quantitative and qualitative data were collected using Torrance Test of Creative Thinking, Creative Solution Diagnosis Scale and an open-ended questionnaire. The control group comprised 30 students while 32 students formed the intervention group. Quantitative data was analysed using Paired Sample T - Test, Wilcoxon Signed Rank Test and Mann-Whitney U Test. The feedback from the participants who completed the intervention programme collected through questionnaires was analysed using Thematic Analysis. The findings of this study illustrated that the module was successful in improving the students' ability in Fluency, Originality, Elaboration and Resistance to Premature Closure creative thinking abilities. The module also facilitated the students' ability to design more creative product. The conclusion was that the creative ability of engineering undergraduates could be improved via creative thinking training. The implications from this research suggested that creativity education would be able to improve the creative ability of engineers and facilitate them in the process of designing more creative products.

PEMBANGUNAN MODUL KEMAHIRAN BERFIKIR KREATIF UNTUK PROSES REKA BENTUK KEJURUTERAAN

ABSTRAK

Objektif kajian ini adalah untuk merancang dan mengembangkan modul kemahiran berfikir kreatif bagi proses reka bentuk kejuruteraan di peringkat pengajian tinggi. Kajian ini juga bertujuan untuk menilai keberkesanan modul yang dibangunkan dalam meningkatkan kemampuan kreatif pelajar sarjana muda kejuruteraan. Modul ini dibangunkan menggunakan model reka bentuk instruksional ADDIE. Kaedah gabungan digunakan dalam fasa penilaian di universiti yang dikaji. Peserta kajian dipilih daripada pelajar tahun tiga kejuruteraan yang menyertai modul berkaitan reka bentuk kejuruteraan lanjutan. Data kuantitatif dan kualitatif dikumpulkan dengan menggunakan Torrance Test of Creative Thinking, Creative Solution Diagnosis Scale dan sebuah soal selidik terbuka. Kumpulan kawalan terdiri daripada 30 orang pelajar manakala 32 orang pelajar lagi membentuk kumpulan intervensi. Data kuantitatif dianalisis menggunakan Paired Sample T-Test, Wilcoxon Signed Rank Test dan Mann-Whitney U Test. Maklum balas peserta yang menyempurnakan program intervensi dikumpul daripada soal selidik dan dianalisis menggunakan Analisis Tematik. Dapatan kajian menunjukkan bahawa modul ini berjaya meningkatkan kemahiran pemikiran kreatif para pelajar dalam Fluency, Originality, Elaboration dan Resistance to Premature Closure. Modul ini juga berjaya mempermudahkan rancangan pelajar untuk mereka produk yang lebih kreatif. Kesimpulannya adalah, kemampuan kreatif pelajar sarjana muda kejuruteraan dapat dipertingkatkan melalui latihan pemikiran kreatif. Dapatan daripada penyelidikan ini menunjukkan bahawa pendidikan kreativiti dapat meningkatkan kemampuan kreatif jurutera dan memudah cara dalam proses mereka bentuk produk yang lebih kreatif.

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4IR	4th Industrial Revolution
ADDIE	Analysis-Design-Development-Implement-Evaluate
BEM	Board of Engineers Malaysia
CAT	Consensual Assessment Tool
CO	Course Outcome
CPSS	Creative Product Semantic Scale
CQI	Continuous Quality Improvement
CSDS	Creative Solution Diagnosis Scale
CSFF	CTSM Students' Feedback Form
CTSM	Creative Thinking Skills Module
EAC	Engineering Accreditation Council
ID	Instructional Design
IHL	Institute of Higher Learning
MOHE	Ministry of Higher Education
MQA	Malaysia Qualification Agency
OBE	Outcome Based Education
PEO	Programme Educational Outcome
PO	Programme Outcome
TTCT	Torrance Test of Creative Thinking

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The society that we live in nowadays is changing more rapidly than we could ever imagine. The era of information explosion brought about by the advancement of new technologies had resulted in changes to the way humans communicate with one another and lifestyle changed tremendously over the decades. Such changes in the society has brought about new needs as well as new problems that are waiting to be solved. The solutions to these new needs and problems would definitely require the current generation of youths, especially students to be more equipped with different skills such as creativity in order to survive and to excel.

In light of this, more and more researchers in the education line and industry have come to realise and recognise the significance of creativity among engineering

practitioners. The ever changing nature of engineering practice, makes it crucial for engineers to maintain a balance between creative thinking and practical knowledge. Therefore, nurturing students' creative capabilities would definitely enable the students to be able to deal with such changes (Anne Eskelinen, 2019; A. Martin Erro, 2016; Siu, 2012).

This study focuses on enhancing creativity of engineering undergraduates through the development of a creative thinking skills module (CTSM) named Creative Thinking Skills for Conceptual Engineering Design Module and administer it to engineering undergraduates.

This chapter begins with introduction the various definitions of creativity in engineering, followed by the background of the research, and the rationale why creativity is so important nowadays for future engineers. This chapter also put forward the relevant research objectives, research questions and research hypotheses. The chapter then continues with the research frameworks, significance of this research, as well as the limitations in the research conducted. Lastly, the chapter ends with brief explanation on the thesis structure.

1.2 Research Background

What is creativity? Creativity comes in various forms and definitions, such that there is no single rule, form or definition is able to capture all essences of creativity. Creativity is the capability of a person to come up with new objects or designs beyond old concepts, methods and ideas using existing knowledge (Shahab Abbaszadeh, 2018; Lin, 2012; Wang, 2007). It is considered also as the ability to come up with the production of a novel, original, and socially useful object, process or idea, and ingenious solutions to problems (Ghosh, 2004). Jonathan and Mathew (2010) pointed out that creativity is becoming a popular topic in not only in the world of education, but also in economic and political circles throughout the world (Jonathan & Mathew, 2010). Anne & Riikka (2019), Martin et al (2016) and Terkowsky & Haertel (2013), are just some of the many researchers who are of the opinion that creativity is one of key skills of the 21st century and a vital factor for the survival of a knowledge based society in coping with problems (Anne Eskelinen, 2019; A. Martin Erro, 2016; Terkowsky & Haertel, 2013).

In 2006, The Partnership for 21st Century Skills, in collaboration with the Conference Board, Corporate Voices for Working Families, and the Society for Human Resource Management conducted an in-depth study to determine the skills that employers are looking for nowadays. The study identified that creativity/innovation as skills necessary for the 21st century. (Casner-Lotto & Benner, 2006). Table 1.1 illustrates the skills listed in the executive summary of the survey.

The survey also reported that Creativity/Innovation is projected to “increase in importance” for future workforce entrants, according to 73.6% of employer

respondents. This suggested that creativity/innovation should be given more emphasis in engineering education.

Table 1.1

List of Skills Necessary for 21st Century (Casner-Lotto & Benner, 2006)

Basic Knowledge/Skills	Applied Skills
English Language (Spoken)	Critical Thinking/Problem Solving
Reading Comprehension (English)	Oral Communication
Writing in English	Written Communication
Mathematics	Teamwork/Collaboration
Science	Diversity
Government/Economics	Information Technology Application
Humanities/Arts	Leadership
Foreign Languages	Creativity/Innovation
Geography/History	Life Long Learning/Self Direction
	Work Ethic/Professionalism
	Social Responsibility/Ethics

For the past two centuries, engineers are responsible for a large portion of major technological breakthrough (Puccio & Cabra, 2010). Now, more than ever, the world is in need of engineers who are able to solve present and future challenges as well as problems (Twohill, 2012). This is mainly due to the fact that design and problem solving activities form an integral part of engineering. The challenges brought forward by the Fourth Industrial Revolution (4IR) should not be ignored or taken lightly.

Creativity is needed when engineers design products, systems, or even solving complex engineering problems. This means that engineers are involved in the business

of creativity directly. Thus, creativity is not just an essential skill, but it is also an indispensable quality of engineering that must not be neglected. Unfortunately, schools around the world, including Malaysia, are not doing enough in supporting these 21st-century learning skills development which includes creativity (Brand, Hendy, & Harrison, 2015; Robinson, 2013; Terkowsky & Haertel, 2013; Haertel, Terkowsky, & Jahnke, 2012; Daud, Omar, Turiman, & Osman, 2012; Beghetto, 2010; Kazerounian & Foley, 2007). In many cases, new technologies that are applied in the world of education are simply just reinforcing the old ways of teaching and learning. (Resnick, 2007).

For engineering sector, five countries and region have developed their own national framework/manual for their engineering graduates and employers, where traits /attributes /qualities /skills heavily related to creativity were identified to be one of the required attributes of engineering graduates (Yuzainee, et al., 2012).

Engineering education providers around the world are now required and expected to produce highly skilled, creative, and innovative engineers. This means that teaching the skills of creativity and innovation has become more essential compared to the past (Lim, Yusof, & Ismail, 2018; Orhun & Orhun, 2013). In light of this, many educators and researchers had conducted numerous researches around the world with the aim to develop various approaches and methods so that in the early stages of design, the development of creative ideas can be further enhanced (Valentine, Belski, Hamilton, & Adams, 2019; Carpenter, 2016; Cropley D. H., 2015; Beghetto, 2010; Cropley A. , 2001).

In the Malaysian context, Malaysia had evolved from a production-based to knowledge-based economy thus enabling Malaysia able to stay upfront, relevant and competitive in the global marketplace over the past few decades. To face the challenges brought forward by 4IR, with its complex environmental, social and economic pressures, young engineers of today must be creative, innovative, and enterprising and be equipped with the motivation, confidence and skills to use creative thinking meaningfully (Edward, 2018).

As such, the need to develop competent human capital to address the challenges brought by the impact of 4IR falls on the shoulder of the education systems in Malaysia. This means that the pivotal role played by the country education system is of crucial importance and should not be taken lightly. The National Education Policy of Malaysia clearly emphasises the need to develop individuals who have the capability to contribute to the advancement of society and nation.

In an effort to reposition the Institutions of Higher Learning (IHLs) in Malaysia to meet the needs emphasized by industries impacted by 4IR, a more dynamic and relevant curricula and pedagogy is required. Thus, educational service providers in Malaysia, in particular the engineering education providers need to be radically improved. In particular, there is a need to inculcate creative thinking, and drive greater innovation and competition in education. A sound creative thinking process is imperative to social progress (Edward, 2018).

A well-designed higher education curriculum should include creativity, innovation, leadership and entrepreneurship. Such curriculum would be able to equip

students with appropriate skills to enable them to compete with the challenging global market as well as overcoming challenges in the era of 4IR (Lieu, Duc, Gleason, Hai, & Tam, 2018; Selvaraj, Anbalagan, & Azlin, 2014).

Realising and recognizing the importance of creativity, the Ministry of Higher Education (MOHE) of Malaysia, has included thinking skills as one of the important attribute of student in the National Education Blueprint 2015-2025 (Higher Education). The definition of thinking skills is to appreciate diverse views, is able to think critically and be innovative, has problem-solving initiative, and an entrepreneurial mind set (MOHE, 2015).

In the Malaysian engineering education context, the Engineering Accreditation Council (EAC) placed creativity as one of the important feature to be included in the curriculum. This is clearly stated in the EAC manual 2020 edition. According to EAC, engineering is defined as “the creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function, economics of operation or safety to life and property” (EAC, 2020).

1.3 Problem Statement

Given the economy transformation that requires the IHLs to include creativity education in the engineering syllabus, more attention that is appropriate should be given for better employability of our engineering graduates.

Safarin et al (2013) through his studies concluded that proficiency of Creative Thinking and Problem Solving Skills for skilled workers in Malaysia do not meet the requirement of employers (Safarin, Md, Khair, & Yahya, 2013). The finding is also in line with the findings from Azami et al (2009), and Fairuzza et al (2011), which stated that, the gap occurs because of the fundamental was not strengthened when they were still studying in IHLs (Fairuzza, Nazuir, & Wahid, 2011; Azami, Mohd., Hassan, Norhamidi, & Farah, 2009).

Recent research on skills gap analysis by Kamaruzaman et al (2019) also indicated that creativity is among the top 10 skills that is still lacking in our engineering undergraduates from the perspective of engineering educators (Kamaruzaman, Hamid, Mutalib & Rasul, 2019). This was supported by many past researches conducted locally such as Johari (2011), Heong (2011), Ayob (2011), Nordin (2012), Hilal (2013), Soon and Quek (2013), Lim (2017) and Tawie (2017).

However, past research activities related to creativity education particularly for engineering design courses in Malaysia was not well documented, developed or established to date (Afida, Aini, Mohd, & Rosadah, 2012; Madar, E. S, & Hamid, 2019). With respect to the above said matter, this research aimed to design and develop

a CTSM to cater for engineering undergraduates who were enrolled in an advanced engineering design related module, studied the effectiveness of CTSM in improving the creativity of engineering undergraduates in a local private IHL.

1.4 Research Objectives

Based on the problem statement, four objectives had been identified for this research. These objectives are:

1. To identify the components of creativity that is related to engineering design.
2. To assess the current creativity level of Malaysian engineering undergraduates in the university involved in this study.
3. To design and develop a CTSM based on the components identified for engineering undergraduate undertaking engineering design course.
4. To assess the effectiveness of the CTSM in improving engineering undergraduates' creativity.

1.5 Research Questions

In this research, the four research objectives were further developed into these following research questions:

Objective 1:

1. What are the components of creativity that engineering undergraduates should be equipped with?

Objective 2:

2a. What is the current creativity level for engineering undergraduate in the studied university?

2b. What are the obstacles in enhancing engineering undergraduates' creativity level?

Objective 3:

3a. What are the skills to be included in the content of the developed module on Creative Thinking?

3b. What is the preferred method of intervention to be applied for the developed module on Creative Thinking?

Objective 4:

4a. How effective is the developed module on Creative Thinking Skills in improving engineering undergraduate creativity level?

4b. How effective is the developed module on Creative Thinking in facilitating students' creativity in designing the product?

4c. What is the feedback from the engineering undergraduates regarding the Creative Thinking module?

1.6 Research Hypothesis

Based on the above research questions, the null hypotheses below were formed:

H_{1a}: There is no significant difference in pre-test and post-test scores in **Fluency** in intervention group.

H_{1b}: There is no significant difference in pre-test and post-test scores in **Fluency** in control group.

H_{2a}: There is no significant difference in pre-test and post-test scores in **Originality** in intervention group.

H_{2b}: There is no significant difference in pre-test and post-test scores in **Originality** in control group.

H_{3a}: There is no significant difference in pre-test and post-test scores in **Elaboration** in intervention group.

H_{3b}: There is no significant difference in pre-test and post-test scores in **Elaboration** in control group.

H_{4a}: There is no significant difference in pre-test and post-test scores in **Abstractness of Title** in intervention group.

H_{4b}: There is no significant difference in pre-test and post-test scores in **Abstractness of Title** in control group.

H_{5a}: There is no significant difference in pre-test and post-test scores in **Resistance to Premature Closure** in intervention group.

H_{5b}: There is no significant difference in pre-test and post-test scores in **Resistance to Premature Closure** in control group.

H_{6a}: There is no significant difference in pre-test and post-test scores in **Overall Figural Creativity** in intervention group.

H_{6b}: There is no significant difference in pre-test and post-test scores in **Overall Figural Creativity** in control group.

H_{7}: There is no significant difference in **Relevance and Effectiveness** scores between control group and intervention group.

H_{8}: There is no significant difference in **Problematization** scores between control group and intervention group.

H_{9}: There is no significant difference in **Propulsion** scores between control group and intervention group.

H_{10}: There is no significant difference in **Elegance** scores between control group and intervention group.

H_{11}: There is no significant difference in **Genesis** scores between control group and intervention group.

H_{12}: There is no significant difference in **Overall Product Creativity** scores between control group and intervention group.

1.7 Research Frameworks

Research frameworks play an important part in the planning and execution of research in both quantitative and qualitative research. Research framework consist of theoretical framework and conceptual framework.

Theoretical frameworks provide the researcher with the knowledge of the existing theories that support the study. It also comprises relationships, theories and research findings that can be applied to explain predict and describe relationship among concepts (Chua, 2016).

Conceptual framework on the other hand is the framework that presents the main variable of the study and their association. Conceptual frameworks are usually built after researcher had conducted careful review of theories and research evidence related to the variables of the study (Chua, 2016).

1.7.1 Theoretical Framework

Creativity has been defined in many ways. There is no single definition of creativity that is able to encompass all ideas. In 1961, Rhodes had classified the various forms of definitions of creativity into four different categories i.e. the famous Four Ps. These categories are 1) Process, 2) Person, 3) Press, and 4) Product (Rhodes, 1961).

The creative "Process" is related to the stages of creative process working in the psyche of the creator himself. It is also referring to the creator's behaviour that contributes to creative achievement. It is also applicable to the creator's motivation, perception, learning, thinking and communication (Rhodes, 1961).

The creative "Products" are the physical manifestations of creative thoughts by the creator. The products are usually evaluated based on their effectiveness and relevance, novelty and also usefulness (Rhodes, 1961).

The creative "Person" on the other hand refers to the potential for creative achievement. From the perspective of Creative "Person", this is related to a set of characteristics of the person such as intellect, temperament, habits, attitudes etc (Rhodes, 1961).

The creative "Press" is related to the relationship between the human beings and their environment. It is the impact the environment has on the creator that facilitates creativity (Rhodes, 1961). Figure 1.1 illustrates the Creativity as defined by Rhodes (1961).

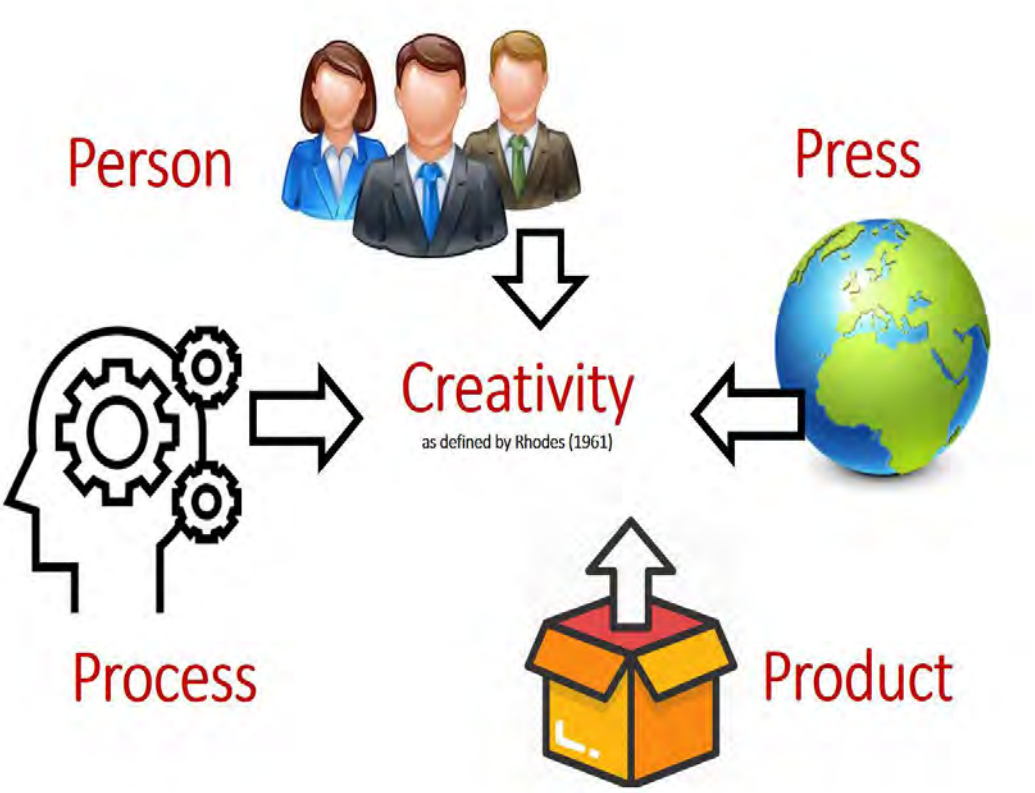

Figure 1.1. The Four Ps of Creativity as defined by Rhodes (1961)

1.7.2 Conceptual Framework

Conceptual framework is the researcher's plan on addressing and exploring the research problem. It is built on a theoretical framework that lies within existing knowledge. A conceptual framework consist of concepts that are operationally defined such that these concepts can be transformed into measurable variables. From a different perspective, conceptual framework specifies the variables so that they can be measured quantitatively or qualitatively.

In this study, the research is about enhancing the creativity of the local engineering undergraduates. When dealing with students who are enrolled in any engineering design module, the students' perception and ability to come up with creative ideas and to design creatively need to be enhanced through teaching and learning process that can be carried out both inside or outside the classroom. The designed product or solution to a problem, which is a manifestation of student's capability to design or come out with some solutions creatively, need to be addressed and evaluated to validate the creativity level of the students. These engineering students as well as the final product must be able to demonstrate certain traits of creativity in the end.

Engineers apply both technical knowledge and soft skills to come out with solutions to problems, in a tangible form, thus the creative "Product". The product must be able to effectively solve problem(s) and be relevant to the on-going issue(s). Thus, relevance and effectiveness of the product must be the first line of evaluation of creativity of product.

Apart from this, a creative product must be able to indicate certain level of novelty or originality when compared to other solutions or products (Cropley D. H., 2015). The product or solution must be able to show case some sort of "out of the box" characteristics, different from the current or existing methods. This means that the design is not just able to cater for the solution to current shortcomings but also able to provide beholders fundamentally, a new perspective and possible solutions.

Another two criteria that enables a product to be considered creative would be the elegance and genesis. The elegance of the product refers to the inherent properties of the product that is able to wow the users/assessors of which the product is targeting. Genesis is the ability of the product to solve future problem without even realising it (Cropley D. H., 2015).

According to Rhodes, creative "Process" are abilities that can be taught and it has been taught in many institutions and industries in the USA. (Rhodes, 1961). Students enrolling in the engineering design module are supposed to be equipped with these abilities, for instance instilled with the right skills such as creative thinking skills that favours creativity.

Creative people are different from their non-creative counterparts in many ways especially when it comes to their personality traits. According to Amabile (1989), creative people are willing to take risks, thus they are risk takers (Amabile, 1989), while Cropley (2001) indicated that these people are non-conformist (Cropley A. , 2001). Creative people also derive great pleasure in discovering and innovating (Claxton, Edwards, & Scale-Constantinou, 2006). Creative thinking, the perception of oneself as being creative and capable of creative productions is also another important factor that requires more attention.

J. P. Guildford, E. P. Torrance, J. W. Getzels, P. W. Jackson are among other prominent researchers of creativity who had contributed many ideas about creativity. The ideas brought forward by Guildford and Torrance is still widely used currently.

Guildford (1959) introduced the four creative thinking skills or abilities, namely Fluency, Flexibility, Originality and Elaboration (Guildford, 1959)**.**

Torrance developed one of the most prominent tool to assess creativity: Torrance Test of Creative Thinking (TTCT), which was built and based upon Guildford's definition of creativity that measure all four skills and abilities as defined by Guildford (Torrance E. P., 1974).

In the 1984, the third edition of TTCT was introduced, Torrance eliminated the Flexibility from the figural test, but added Resistance to Premature Closure and Abstractness of Titles as two new scores on the Figural Creativity. Torrance called the new scoring procedure Streamlined Scoring (Kim, 2006). This research employed the latest edition of TTCT.

Figure 1.2 illustrates the conceptual framework applied in this research. The conceptual framework is important as it is an organised way of thinking and is used to demonstrate how the research is being carried out, what are the steps involved, and why is it carried out. This research applied the definition of Process and Product as defined by Rhodes (1961), Torrance (1984) and Cropley (2015) respectively to explore the ways to improve creativity of engineering undergraduates.

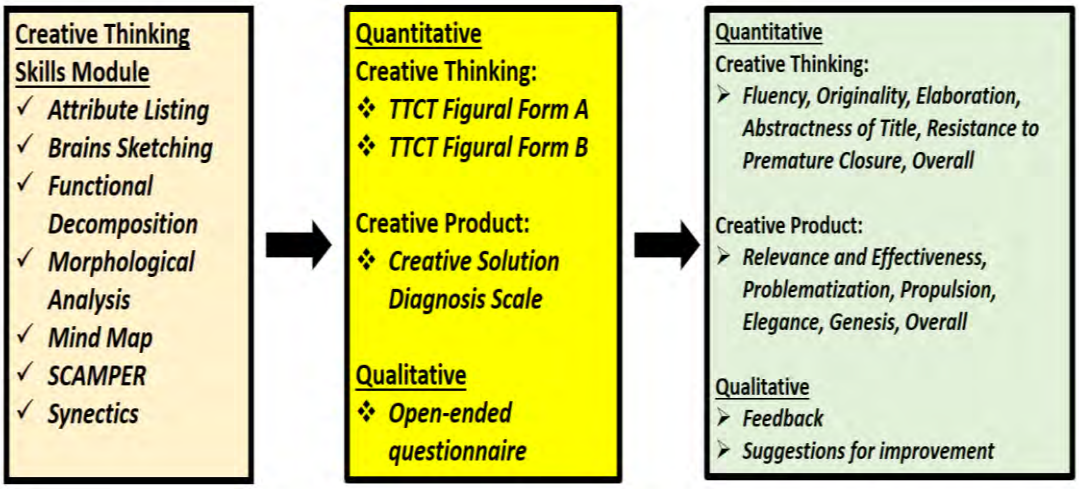

Figure 1.2. Conceptual Framework

1.8 Operational Definitions

In this section, a few terminologies frequently used in this study will be clarified. This is to ensured precision and lucidity in the understanding of operational concept.

1.8.1 Creativity

For the purpose of this study, creativity will address the specific area with relevance to the creative thinking of the students. Creative thinking is regarded as a creative process occurring inside the students' brain when it comes to information processing. Students' ability to produce creative product, measured in the product creativity, where it is the manifestation of the students' creative ability will be second to be addressed in this study.

1.8.2 Process

Torrance (1966) further continued the research by Guildford (1959) and Rhodes (1961) in creativity. Torrance derived his own definition of creativity subsequently. He defined it as a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies and so on; identifying the difficult; searching for solutions, making guesses or formulating hypotheses about the deficiencies; testing and retesting these hypotheses and possibly modifying and retesting them, and finally communicating the results. In this study, studied participants are to be equipped with creative thinking skills by participating in the intervention programme.

1.8.3 Product

The creative product in this research project will be the product designed by engineering undergraduates involved in this study upon completion of the intervention programme during the semester while undertaking the advanced engineering design module. Cropley (2015) had worked on the definitions and characteristics of a creative product that will have the criteria of relevance and effectiveness, problematization, propulsion, elegance and genesis, which will be discussed in later section of this chapter.

1.8.4 Torrance Test of Creative Thinking

Torrance with his definition of creativity developed one of the most prominent tools for measuring creativity, and it is known as the Torrance Test of Creative Thinking (TTCT). TTCT is the most well-known and widely used instrument for measuring creativity (Annie & Lee, 2019; Hahm, Kim, & Park, 2019; Madar, E. S, & Hamid, 2019; Almeida, Prieto, Ferrando, Oliveira, & Ferrandiz, 2008). TTCT consists of Figural Creativity and Verbal Creativity tool for assessment. For this study on engineering undergraduate students, Figural Creativity of the students is assessed. Figural Creativity is the measure of the five different abilities listed below inherent in the creative process.

1.8.5 Figural Fluency

Figural fluency is defined as the ability of the student to produce a number of relevant figural images. The term Fluency will be used throughout all the chapters in replacement of Figural Fluency.

1.8.6 Figural Originality

Figural originality is defined as the ability of students to produce statistically infrequent or uncommon responses. The term Originality will be used throughout all the chapters in replacement of Figural Originality.

1.8.7 Figural Elaboration

Figural elaboration is defined as the ability of students to develop, embroider, embellish, carry out and elaborate ideas. The term Elaboration will be used throughout all the chapters in replacement of Figural Elaboration.

1.8.8 Abstractness of Title

Abstractness of Title is defined the ability of the students in synthesising and organizing process of thinking. The term Abstractness will be used throughout all the chapters in replacement of Abstractness of Title.

1.8.9 Resistance to Premature Closure

Resistance to Premature Closure is defined as the ability of students to keep open and delay closure long enough to make a mental leap that makes original idea possible. The term Closure will be used throughout all the chapters in replacement of Resistance to Premature Closure

1.8.10 Overall Figural Creativity

Apart from the five above mentioned Figural Creativity abilities, this study will also include a new measure of Overall Figural Creativity.

Overall Figural Creativity is defined as the total scores of all five abilities measure in the TTCT. The score will provide a general overview of the creative ability of the studied participants. The term Overall Creativity will be used throughout all the chapters in replacement of Overall Figural Creativity

1.8.11 Studied Participants

The studied participants in this research refers to the local engineering undergraduate students in two different private universities. The first group of studied participants are those who had participated and completed the pilot study. The second group of studied participants are participants who were in the control group and intervention group in the experimental stage in another different private university involved in the study.

1.8.12 Revised Creative Solution Diagnosis Scale

The creativity components of the product can be measured using the revised Creative Solution Diagnosis Scale (CSDS). The revised CSDS developed provides assessment in five different criteria in terms of Relevance and Effectiveness, Problematisation,

Propulsion, Elegance, and Genesis (Cropley D. H., 2015). A total of 24 items were available in the revised CSDS to evaluate the creativity of the product.

1.8.13 Relevance and Effectiveness

This criterion refers to the functionality of the solutions or designs to accurately reflect conventional knowledge or techniques applied, does what it is supposed to do, while fits within task constraints.

1.8.14 Problematization

This criterion refers to the functionality of the solutions or designs proposed to draw attention towards shortcomings in other existing solutions, shows how existing solutions could be improved, and helps the beholder to anticipate likely effects of changes.

1.8.15 Propulsion

This criterion refers to the functionality of the solutions or designs proposed to be able to shows how to extend the known in a new direction, makes use of new mixture(s) of existing elements, indicates a radically new approach, helps the beholder see new and

different ways of using the solution, and offers a fundamentally new perspective on possible solutions.

1.8.16 Elegance

This criterion refers to the functionality of the solution suggested that it is safe to use and environmentally friendly, beholder sees the solution as skilfully executed, well-finished, finds the solution neat, well done, well worked out and "polished", well-proportioned, nicely formed, and elements of the solution fit together in a consistent way.

1.8.17 Genesis

This criterion refers to the functionality of the solution put forward is able to suggest a novel basis for further work, offering ideas for solving apparently unrelated problems, suggests new ways of looking at existing problems, draws attention to previously unnoticed problems, suggests new norms for judging other solutions-existing or new, and opens up a new conceptualization of the issues.

1.8.18 Overall Product Creativity

For this study, an additional measure named overall product creativity is established. The overall product creativity is defined as the total scores of Genesis, Elegance, Propulsion, Problematization, Relevance and Effectiveness. This overall score will provide a general overview of the creativity of the product designed by the studied participants as measured in all criterion.

1.9 Significance of Research

From the employer survey data as well as research activities and analysis conducted by various organisations, it is clear that creativity is one of the essential tools that engineers are required to be equipped with in order to survive in the 21st century workplace (Casner-Lotto & Benner, 2006). Engineers are directly involved with the business of innovation as their job scopes are to design, to innovate and to solve problems.

In the quest to achieve the status of developed nation, Malaysian engineers have a vital role to play. The National Education Blue Print 2015-2025 (Higher Education) had laid a solid foundation for Malaysian IHLs to educate and train the next generation of Malaysia engineers, improving the living environment of fellow Malaysians. To achieve this, engineers require not only technical knowledge and skills, but also creativity and innovation to cater to the needs of future generation. Fostering engineering students' creativity ought to be carried out during their four-year undergraduate education period. By understanding the state of creativity in engineering

undergraduate students, steps can be taken to address any deficiencies through appropriate training and counselling.

This study aims to develop and evaluate an intervention programme targeted at improving the creative ability of local engineering undergraduates based on constructivism theory, cognitive learning theory and creativity theory. Apart from this, it is hoped that this research will be able to contribute to the engineering education field, focusing on creativity research literature resources as well as supplementary learning resource which can provide references to future work in the Malaysia engineering education context.

1.9.1 Curriculum Development

The findings will be able to provide the understanding of the current state of creativity of local undergraduate students taking engineering design module. The findings from this research will also provide insights about the obstacles in implementing the creativity education for engineering education in the Malaysia context.

The research then moves another step further to design and develop a CTSM named Creative Thinking Skills for Conceptual Engineering Design using the ADDIE instructional design model, providing a potential solution to foster and improve the students' creativity without compromising the current engineering programme structure.

The findings have the capacity to impact upon the approaches adopted by engineering education providers to enhance the creativity of their engineering undergraduates. The effect of the intervention programme will significantly contribute to the survival skills of our local engineers in solving complex engineering problem creatively.

1.9.2 Practical Contribution

This study can provide practical contributions to the respective stakeholders in engineering education in Malaysia. These include the Ministry of Higher Education, Board of Engineers Malaysia (BEM), Engineering Accreditation Council, Malaysia Qualification Agency (MQA), engineering education providers, academicians and researchers. These contributions to enhancing the creativity of local engineering undergraduates will be an invaluable asset for future research as well as training for young engineers.

1.10 Research Limitations

Certain limitations arose from this study. These limitations are as listed and discussed in the following sections.

1.10.1 Lack of Documented Relevant Articles Focused in Malaysia

There were many creativity enhancement and intervention programmes research conducted to assess and improve the creativity level of students from primary and secondary schools around the world including Malaysia. However, documented works on improving creativity amongst engineering undergraduate in Malaysia is still not well established.

The lack of previous studies and research findings in creativity education, specifically in engineering education in the Malaysian context has made it difficult to benchmark the effectiveness of the method employed in the intervention programme. Most of the literature available in creativity education in Malaysia are limited to secondary schools and/or non-Engineering related field. Literature review is important because it helps identify the scope of works done so far in the research area. The majority of literature cited in this study are from studies conducted overseas.

1.10.2 Private IHLs' Involvement in Study

The studied universities in this research are private IHLs located in Malaysia that offer engineering undergraduate programmes, namely Bachelor of Mechanical Engineering, Bachelor of Civil Engineering, Bachelor of Electrical Power Engineering, and Bachelor of Electrical and Electronics Engineering. Public IHLs are not considered in this research. For this particular research studied participants were recruited from students enrolled in the Bachelor of Mechanical Engineering.

1.10.3 Sample source and size

The studied participants were recruited from the Mechanical Engineering Department in the studied private IHLs. This was because the department had the highest number of engineering students enrolled. The studied participant was selected from the local mechanical engineering undergraduates who had met the requirement of meeting the pre-requisites and were enrolled in an advanced design module in their third year of study.

1.10.4 Pre-requisite of relevant modules

The studied participants must be enrolled, and obtained passes in basic engineering design technical skills related modules. These design related technical skills involves ability to use CREO, SOLIDWORKS or AutoCAD. The studied participants should be currently enrolled in an advanced engineering design related module. This is to ensure that the studied participants are able to exercise and apply the prior acquired technical knowledge, skills and experience in the product design.

1.10.5 The Researcher Works in The Same Studied University

Some of the studied participants have contact with the researcher directly with student-lecturer relationship. As such, these participants might had been overly cautious and reserved in their responses during the activity sessions, surveys or observations during

the intervention programme. Throughout the intervention programme, two facilitators were employed to facilitate the intervention programme**.** Trainings were provided to the facilitators on the CTSM prior to the intervention programme. This was to ensure the facilitators were well verse with the CTSM and to minimize the impact of the researcher on the respondents in general as well.

1.10.6 Creative Thinking Skills Related to Figural Aspects

Engineers deal much with conceptual design in the form of drawings and hand drawn sketches during product and/or solution design and development. Hence, during the intervention programme sessions, resources, and learning aids developed were focused and related to creativity in the figural aspect as conceptual engineering design involves a lot of sketches and drawings. Creativity relevant to other aspect such as verbal aspect was not be included in the research.

1.10.7 Assessment in Two Categories of Creativity – Process and Product

The assessment of creativity in this study will only look into only two of the creativity categories, i.e. Process and Product. Person and Press are not included in the research. The assessment of Person and Press will involve assessment in the personality and psychological aspect of the respondents, which is not the consideration for this research.

1.11 Thesis Structure

This thesis consists of six chapters

Chapter One provides information about the background of creativity research in the engineering design domain, and delivers the problem statement. It also presents the research objectives, research questions and relevant research hypotheses. The chapter also provides information about the theoretical and conceptual framework applied, as well as the limitations and operational definitions applied in this thesis.

Chapter Two presents reviews on creativity and engineering design education in the Malaysia context. The chapter proposes a module that comprises seven thinking skills to improve the creative ability of engineering undergraduates using ADDIE instructional design model.

Chapter Three provides an overview of the methodology applied. This includes the research methods applied, development and selection of instruments, selection of samples, pilot study, implementation of programme and selection of analytical tools for data collected.

Chapter Four presents an overview of the processes involved in the module development. This includes the Analysis of needs, Design and Development of CTSM, and Implementation of the intervention programme.

Chapter Five presents the results analyzed and collected using the instruments. These results include data from TTCT for creative process, CSDS for creative product and feedbacks and suggestion from open-ended questionnaire.

Chapter Six provides and conclusions and recommendations.