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Curriculum Development for Enhancing the Imagination in the Technology Commercialization Process

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ABSTRACT

The imagination capability in technology commercialization is the key success factor for innovation. However, higher education in general and engineering-related curricula in particular, has offered limited courses incorporating imagination. A complete and well-verified curriculum that will enhance the imagination capability in technology commercialization is critical and imperative to resolve the problem. Thus, this research summarizes possible course modules and the criteria for evaluating and selecting the core modules based upon a literature review. Final criteria were defined by using the modified Delphi method. The influence relationships of each criterion on the others were derived by the Decision-Making Trial and Evaluation Laboratory (DEMATEL). Subsequently, the derivation of critical criteria, a weight was defined for each criterion by using the DEMATEL-based Network Process (DNP). Finally, the correlations between the criteria and the course modules were derived by using the Grey Relational Analysis (GRA). Based on the analytic results, QFD, TRIZ, and SCAMPER courses were recognized by the experts as important for enhancing engineering students' imagination capabilities.

Keywords: technology commercialization, imagination, creativity, multiple criteria decision making, curriculum development

INTRODUCTION

Einstein had ever stated, "Imagination is more important than knowledge. Knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution." Imagination is an agency-focused "possibility thinking" (Craft, Chappell, & Twining, 2008) that is peculiarly suited to be the vehicle of active creativity (Gaut, 2003). Morosini (2010) suggested that imagination could be regarded as the conduit through which the unconscious self would find its way out in the form of creative mental imagery that could drive deliberate actions. Creativity has not only long been considered an important source of innovation and competitive strength for organizations (Udwadia, 1990), but also it has a strong relation with invention and innovation. Without creativity in design, there would be no potential for innovation, with which creative ideas are actually implemented

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State of the literature

- The activity of technology commercialization being related to idea generation, technology development, new product revisions, manufacturing, etc., is seen as an innovation process by innovation capability and creative imagination in product innovation management and product planning (Calantone, Di Benedetto, & Rubera, 2012).
- Chu and Quek (2013) argued that the imagination can be shaped through experiences, and thereby contributes to creative activities; if such creative activities are perceived as new, the products of imagination become creative.
- The key criteria for measuring the imagination capability can be classified as three types: initiating, conceiving, and transforming (Lin, Hsu, & Liang, 2014).

Contribution of this paper to the literature

- The evaluations of imagination enhancement strategies as well as course modules for enhancing imagination in the technology commercialization process are provided in this research.
- This research defines an analytic framework for exploring the influence relationship between evaluation criteria for the course modules for enhancing imagination in the technology commercialization process, deriving the associate weights versus the criteria, and defining appropriate imagination enhancement course modules.
- The analytic framework and research results can serve as a basis for curriculum design for enhancing engineering imagination. The curriculum being developed can be applied to enhance engineering students' imagination capabilities in technology commercialization.

(T. M. Amabile, 1997; Mumford & Gustafson, 1988) and transformed into commercial value (Howard, Culley, & Dekoninck, 2008; Thompson & Lordan, 1999). Because the imagination, creativity and innovation capabilities are essential for successful commercialization of new products or services, a lack of imagination is viewed as problematic in a rapidly changing technology-oriented world, where generating new ideas is essential to survival (Klukken, Parsons, & Columbus, 1997). The more quickly things change, the more imagination one needs to keep up.

Human beings are born with imagination, the major driver for the progress of humankind. Imagination is the source of creativity. Sufficient creativity is the source of innovation. Continuous innovation can propel the long-term development of the national economy. Civilization cannot establish technology and culture without innovation. Innovation depends upon invention. Inventions should be managed and commercialized before contributing towards the growth and profitability of an organization. Thus, innovation includes all technology commercialization activities related to idea generation, technology development, new product or product revisions, manufacturing, etc. Technology commercialization is also called product planning, product innovation management or new products management (Calantone, Di Benedetto, & Rubera, 2012). In many industries, technology commercialization is the most important driving force to compete successfully in modern society.

Most of the companies in industry earned more than one-third of their sales and profit in the past years from the development of new products (Barczak, Griffin, & Kahn, 2009). Owing to globalization, technology commercialization is becoming increasingly important to sustain competitiveness in modern industry. Hence, developing new technology and commercialization of novel technology is profitable for businesses. Investment in process innovation can reduce production costs. An advance in information technology also plays a significant role in accelerating the commercialization of technology. These technologies help companies develop and produce more diversity in products to cater to the needs of minorities and be close to the customer base, thereby achieving differentiation from competitors.

Imagination can be taught (Liu & Noppe-Brandon, 2009). It is widely believed that a child's imagination ought to be stimulated and developed in education (Doiron & Egan, 1993). Yet few teachers understand what imagination is or how it lends itself to practical methods and techniques that can be used easily in classroom instruction (Doiron & Egan, 1993). Industrial leaders have long expressed a mounting concern about the impact of traditional engineering education on the creative potential of future engineers (i.e., lacking design capability or creativity, as well as an appreciation for considering alternatives) (Ogot & Okudan, 2006). Therefore, the stimulation and development of engineering students' imagination capabilities can further enhance the creativity and thus the innovation capabilities of the students. Higher education plays an important role in providing people with skills for innovation, but a number of important questions remain as to what kind of higher education teaching would be conducive to strengthen the skills (Hoidn & Kärkkäinen, 2014) and the imagination as well as the creativity capabilities for innovation. In the past several years, universities in the leading economies have responded to these challenges by adding more design content and introducing more open-ended design problems into their engineering curricula (Ogot & Okudan, 2006). Yet the need persists to increase the creative potential of graduates (McGraw, 2004).

Apparently, the technology commercialization imagination capability is the key success factor for innovation. However, the availability of such a curriculum being available in universities in general, and in engineering, design, management of engineering or technology management related curricula in particular, is still insufficient to fulfill education and industry needs, even in the United States and other developed or developing economies. To resolve the problem and enhance the technology commercialization planning imagination capability, constructing a complete and well-verified technology commercialization curriculum is critical and urgent. Thus, this research summarized possible course modules that could stimulate or enhance engineering students' imagination capability.

The possible course modules include TRIZ, SCAMPER, Quality Function Deployment (QFD), scenario analysis, brainstorming, etc.; the course modules were further derived by using the brainstorming method. Possible decision factors for selecting the course modules were proposed as evaluation criteria based on literature review results and then confirmed by using the modified Delphi method with opinions collected from engineering education experts. Then, using the Decision-Making Trial and Evaluation Laboratory (DEMATEL), the influence relations of one criterion on others were derived. Following the derivation of critical factors, a weight for each criterion was defined using the DEMATEL based Analytic Network Process (DNP). Finally, the relationship between the criteria for evaluating the technology commercialization imagination capability and the imagination course modules was derived, using the Grey Relational Analysis (GRA) by introducing the weights corresponding to each criterion. The most important imagination course modules were selected as the content of the curricula to stimulate and enhance engineering imagination capabilities for technology commercialization.

The definition of the curricula for stimulating and enhancing engineering students' imagination was based on opinions provided by eleven experts in the related fields of engineering design and engineering management. The curricula can be used in the future for developing students' imagination capabilities in concept design and new product development of engineering products.

The remainder of this study is organized as follows: In Section "Literature Review", the concepts of imagination will be introduced. In Section "Research Method", the author will introduce the research methods being used in this research, which include the modified Delphi, the DEMATEL, the DNP, and the GRA. Then, in Section "The GRA Method", the analytic procedure for defining the curricula, will be demonstrated. The major findings, implications, limitations of this research and future research possibilities will be discussed in Section "Discussion". Section "Conclusions" will conclude the whole article with observations, conclusions and recommendations for further study.

LITERATURE REVIEW

Imagination is a basic human instinct. Without imagination, humanity could not have established current technology and civilization. This section will review the literature related to imagination, the differences and relationships between imagination and creativity, imaginative capability, imagination and successful product development, and the evaluation of imagination. The literature review results will serve as the basis to develop a curriculum for stimulating, developing and enhancing the imagination capabilities in the technology commercialization process.

Imagination

Imagination has classically been defined as "an act or process of forming a conscious idea or mental image of something never before wholly perceived in reality by the one forming the images" (Taylor, 2013). The general definition of imagination is, "Imagination is the ability to think of all things as possible" (Kangas, 2010). Imagination is a creative faculty of the mind; it can be viewed as a vital cognitive capacity for learning because "it permits us to give credence to alternative realities" (Heath, 2008). According to Zivkovic et al. (2015), the more comprehensive explanation sees "imagination as an dimension of reflective thinking that enables us to bring about ideas that not only go beyond what are given but are effective, in the sense that they are likely to transform experience as intended".

Imagination is a phase in the process of change; it is produced by culture and society, fed by individual experience; but imagination also feeds-forward, changing individual lives and societies. Imagination is a key phase in the process of change precisely because the imagination is not constrained by what is; rather, imagination is freedom; it is a liminal space, a potential space, in which new ideas, alternatives to the status quo, can be explored (Zittoun & Gillespie, 2015). Most contemporary psychologists define the imagination as a higher mental function that involves the synthetic combining of aspects of memories or experiences into a mental construction that differs from past or present perceived reality and may anticipate future reality (Morosini, 2010).

Imagination is one of the most precious cognitive capacities, the total amount of information the brain is capable of retaining at any particular moment. Imagination can enable people to exceed the real experience and foster the substitute feasibilities. Dewey (1910) explained that imagination is an aspect of reflective thinking, something we learn to do, and we learn to do it from and with other people. The reflective thinking capability enables us to create ideas that not only go beyond what is given but also are effective, in the sense that they are likely to transform experience as intended and relate to the locus of control and creative thinking (Norton, 1994). Above scholars point to the power of imagination as the human capacity that enables us to create fresh perspectives of the world; imagination, along with perception, is an important resource for taking up the aesthetic challenge offered by our natural environment (Brady, 1998).

Scholars have tried to classify imagination based on the characteristics of different activities of human imagination. Betts (1916) classified imagination into reproductive imagination and creative imagination. Kunzendorf (1982) further identified both the idealizing-constructing and transforming characteristics of creative imagination. Reichling (1990) proposed the four facets of imagination as intuition, perception, thinking, and feeling. Colello (2007) divided imagination into two aspects, namely, reproductive imagination and creative imagination. Liu and Noppe-Brandon (2009) supported the claim asserted by Kunzendorf, classified imagination capabilities into three categories: (1) the ability to conjure new realities and possibilities; (2) the ability to unfold in the conscious and deliberate, and in the unconscious and intuitive, and (3) the ability to form associations and analogies between objects that previously seemed disconnected. Fettes and Judson (2010) identified eight functional capabilities of imagination, which included grasping regularity, detail, composition, wholes, possibility, struggle, indices, and inconsistency. Fettes categorized these imaginative capabilities into three groups: (1) grasping the coherence and stability of the world; (2) change, variation, and unpredictability; and (3) the role of integration. Recently, W.-S. Lin, Hsu, and Liang (2014) investigated design majors and categorized their imaginative capability into three types: initiating, conceiving, and transforming.

Imagination and Creativity

Imagination is one of the most precious cognitive capacities and can be perceived as the vehicle of active creativity (Gaut, 2003). To exercise the imagination is to be creative (Levitt, 1986). As stated by El-Murad and West (2004), creativity is often described in such terms as "creative thinking" or "ability," "problem solving," "imagination," or "innovation." Furthermore, according to Im and Workman Jr (2004), creativity is important in marketing strategy since (1) creativity motivates the generation of new ideas, (2) creativity results in product differentiation, which is a critical determinant of a firm's performance and (3) the resource-based theory of the firm suggests that creativity, which is an intangible resource embedded within the firm, can provide a competitive advantage.

Creativity, which has long been considered as an important source of innovation and competitive strength for organization (Udwadia, 1990), refers to the generation of novel and useful ideas concerning products, services, process, and procedures (T. Amabile, 1996; Chen, Chang, & Chang, 2015). Barron and Harrington (1981) stressed that two primary categories of definitions have been used in large bodies of research: (1) creativity as an ability manifested in performance in critical trials (e.g., Silvia et al., 2008); (2) creativity as socially recognized achievement in which there are novel products that one can point to as evidence (e.g., Baer, Kaufman, & Gentile, 2004).

Creativity is an integral and essential part of the engineering design process (Howard et al., 2008). There is no potential for innovation without creativity in design, which is where creative ideas are actually implemented (Mumford and Gustafson, 1988 and Amabile, 1996) and transformed into commercial value (T. M. Amabile, 1997; Mumford & Gustafson, 1988). To emphasize this importance, recent figures were released from the UK treasury concluding that the top innovating companies produced 75% of revenue from products or services that did not exist 5 years ago. Within industry, creativity does not necessarily equate to success. However, based on the above observation, long-term failure is a near certainty without creativity (Howard et al., 2008).

Concerning the relationship between imagination and creativity, Perdue (2003) explained that imagination can be defined as ''a creative faculty of the mind.'' Gaut (2003) also contended that imagination is peculiarly suited to be the vehicle of active creativity. Besides, he held that the creative person imagines various propositions, and believes that it is possible that the next option tried will be the correct solution (Gaut, 2003). Similarly, Craft et al. (2008) proposed that imagination is an agency-focused "possibility thinking". Moreover, Morosini (2010) suggested that imagination could be regarded as the conduit through which the unconscious self would find its way out in the form of creative mental imagery that could drive deliberate actions. In general, imagination is the basis for cultivating creative thinking and, thus, a driving force of innovation (Finke, 1996). Chu and Quek (2013) argued that experience shapes imagination, and imagination contributes to creative activity; if the output of creative activity is "perceived as new, the products of imagination become creative when they enter the cultural world of interaction". Imagination can be used as a semiotic tool of engagement, which is transformative in the sense that learners become more knowledgeable in their thinking (Egan, 2005). Trotman (2006) stated that imagination is an essential human capacity in conducting various activities such as the pursuit of creativity and innovation, the symbolic expression of ideas, and critical thinking. Baskinger and Nam (2006) further explained that designers often engage in activities involving the visualization of ideas, which primarily relies on their imagination.

Imagination and Successful Product Development

Imagination, a creative faculty of the mind (Heath, 2008) and one of the most precious cognitive capacities, can be perceived as the vehicle of active creativity (Gaut, 2003). Creativity has long been considered an important source of innovation and competitive strength for organizations (Udwadia, 1990). Therefore, it is no wonder that by mining some idea generation software(s), the word "new product" retrieves several associated words and phrases such as marketing, imagination, research experiments, and so on (Rangaswamy & Lilien, 1997). According to the research result derived by Stevens, Burley, and Divine (1999), the correlations are positive between profits generated from new product development projects and the degree of creativity of those projects. In general, imagination is the key driver of creativity. Creativity can further drive successful innovation, which can generate profits.

In a typical new product development process, marketing activities play significant roles in the customer need identification, target specification establishment and product concept generation. For example, Ulrich (2003) included customer need identification, target specification establishment, product concept generation, selection and test, etc. in the generic process of new product development. Unfortunately, marketing programs for many established products fall short in terms of creativity (Andrews & Smith, 1996). Therefore, Theodore Levitt, the Harvard Business School's "guru of marketing", proposed that marketing imagination is the starting point of success in marketing (Levitt, 1986). Concept development and design also play dominant roles in the early stage of the new product development process. In the role of concept creator, product managers need imagination and active, holistic ways of thinking (Zhang & Doll, 2001). Further, according to Luttropp (2006), design is creative and creativeness is about knowledge, fantasy and imagination (Luttropp & Lagerstedt, 2006).

Apparently, imagination is the key factor for influencing creativity in product marketing, concept development, and design. Therefore, incorporating product development success and failure measurement factors is essential in evaluating the methods or courses for stimulating imagination. The methods with low relationship to successful development of products are less valuable for engineering students. According to the work by Griffin and Page (1993), the factors for measuring the product development success or failure include customer acceptance measures, financial performance, product level measure, and firm level measure. According to the definition of Griffin and Page (1993), the customer acceptance measure includes customer acceptance, customer satisfaction, and met revenue goals, revenue growth, market share goals, and unit sales goals. The financial performance measure includes break-even time, attain margin goals, attain profitability goals, and IRR/ROI. The product-level measures include development cost, launched on time, product performance level, met quality guidelines, and speed to market. Finally, the firm-Level measures include the percentage of sales by new products.

Evaluation of Imagination

Imagination has been assessed in many different ways depending on the requirements of the study in question. The issue of a general assessment measure of imagination is complicated by the various ways in which the concept has been understood (e.g., it has previously been equated with memory, imagery, fantasy, invention or creativity). Some of the common measures that have been used include the numerous types of inkblot tests, textual measures (sentence building, story creation based around certain words, descriptions of imaginary animals, compositions, theme writing), studies of dreams and fantasy, or various scales depending on the definition adopted. However, Liang, Chi-Cheng, Chang, and Li-Jhong (2012) argued that the understandings of imagination and its indicators remain unclear. So far, few studies have clearly discussed how imagination manifests itself, let alone developed an evaluation tool for assessing imagination (Liang et al., 2012). Because of the potential applicability to the profession of educational technology and various fields, some general concepts of imagination must be explained before referring to them, specifically indicators that might be observed or assessed (Liang et al., 2012). According to the work by Lin et al. (2014), the evaluation criteria for imagination capability can be classified as three types: initiating, conceiving, and transforming (W.-S. Lin et al., 2014). The initiating imagination, the ability to productively conjure new possibilities and a structure in consciousness that negotiates and explores between the known and unknown (Folkmann, 2010), can further the imagination capabilities, which include exploration, novelty, and productivity. The conceiving imagination, the capability to grasp mentally the core of a phenomenon utilizing personal intuition and sensibility, and the capability to formulate effective ideas for achieving a goal through concentration and logical dialectics (Cartwright & Noone, 2006), can be divided into concentration, sensibility, intuition, effectiveness, and dialectics. Finally, the transforming imagination, the capability to crystallize abstract ideas and reproduce what is known across different domains and in various situations (Liu & Noppe-Brandon, 2009; Perdue, 2003; Vygotsky, 2004), can further be classified into crystallization and transformation capabilities.

By summarizing the evaluation criteria for imagination capability proposed by W.-S. Lin et al. (2014) and the key factors for measuring the product development success or failure, the aspects and criteria are summarized below in **Table 1**. These aspects and criteria will serve as the basis for developing the analytic framework for curricula that can stimulate imagination capabilities for commercialization of new products. The corresponding symbols for the aspects and criteria are also defined in **Table 1**.

Table 1. Descriptions of Criteria for Evaluating Imagination Capability

Aspects	Criteria	Descriptions
Initiating Imagination (D_1)	Exploration (c_{11})	Exploration includes things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, innovation (March, 1991). Imagination can be seen as a structure in consciousness that negotiates, exchanges, and explores between the known and unknown (Folkmann, 2010). Exploration is the initial stage of the mental process being proposed by Valett (1983). The process of controlled perceptual exploration takes individuals from a vague appreciation to a detailed understanding of reality (Thomas, 1999). Colello (2007) asserted that imagination allows one to explore, dare, and challenge institutional order, and thus overcome limits.
	Novelty (c_{12})	Imagination builds using materials supplied by reality; however, it would be productive from using combinations of concepts that are more removed from reality (Vygotsky, 2004). An imaginative person is good at creating the new possibilities, and able to offer fresh perspectives on what is familiar (Beaney, 2005).
	Productivity (c_{13})	Imaginative might be able to come up with original ways of seeing or doing things in a short period (Beaney, 2005). Imagination relates to the start of the design process as either an overall conception of the design as a whole, or a more experimental exploration for details (Folkmann, 2010). Both positions clearly state the success criteria for the design task in terms of productivity (Liang et al., 2012).
Conceiving Imagination (D_2)	Concentration (c_{21})	Development of self-control is related to the ability to create and sustain an imaginative scenario (Vygotsky, 1980). Folkmann (2010) claimed that the process of focusing is open to ongoing reformulation.
	Sensibility (c_{22})	All forms of creative imagination imply elements of feelings, which are not merely inner states, but are really "interiorized thoughts" (Scheffler, 2010). Feeling, in terms of imagination, is assigned a cognitive dimension (Reichling, 1990). Even if the construct of the imagination does not correspond to reality, the feelings it evokes are real (Gajdamaschko*, 2005). Sensibility is thus concluded to be an indicator of imagination, which represents the ability for individuals to arouse feeling during the creating process (Liang et al., 2012).
	Intuition (c_{23})	Intuition could be defined as an immediate mode of knowing, knowledge gained directly as an insight, or a grasp of the whole (Reichling, 1990). The insight may occur as a leap from the known to the unknown in the manner can also be described: "When old and new jump together, like sparks when the poles are adjusted, there is intuition" (Dewey, 2005). Intuition leads people to test various thoughts, and possibly gain unexpected outcomes (Reiner & Gilbert, 2000). If people utilize more intuitive representations, then their imagination would last longer (Townsend, 2003).
	Effectiveness (c_{24})	Imagination is influenced directly by the constitution of end products and confined within certain constraints (Ribot, 1906). Imagination thus could be examined by the inventions' effectiveness. Imagination is goal-oriented, based on prior experiential imagery (Reiner & Gilbert, 2000). A sharp focus in imagination will often be associated with a goal-oriented process that is close to the given requirements as stated by the client (Folkmann, 2010).
	Dialectics (c_{25})	DeVries (1988) asserted that imagination goes through a process of abstraction, analysis, and generalization. When discussing the final level of imagination, Reichling (1990) indicates that intuition leaps for the unknown, while reason is continually challenged to find an image that resolves the contradictions with which it is presented. Also, within their imagination, people can 'zoom in and out' to inspect particular imaginary situations, transfer objects, and predict paths of imaginary objects (Reiner & Gilbert, 2000). Therefore, dialectics can be viewed as an indicator of imagination, which represents the ability of individuals to seek improvement through analyzing ideas (Liang et al., 2012).

Table 1 (continued). Descriptions of Criteria for Evaluating Imagination Capability

Aspects	Criteria	Descriptions
Transforming Imagination (D_3)	Crystallization (c_{31})	According to Aristotle, imagination bridges "images" and "ideas," (Perdue, 2003). In Hegel's theory of mental activity, imagination connects "abstract properties" and "concrete universals" by law of association (DeVries, 1988). No matter the form, imagination can facilitate people's abstract ideas into concrete subjects (Ribot, 1906). Vygotsky believed that imaginative activities are crystallized in culture; all objects of common life appear as a crystallization of the imagination (Vygotsky, 2004).
	Transformation (c_{32})	The essential element of imagination in the intellectual sphere is the capacity of thinking through analogies (Ribot, 1906). The core principle behind analogy is transformation. Vygotsky and Luria (1994) stressed that the transformation enables children to learn how to control a situation through the use of symbols. Imagination assists people in transferring a function from one object to another that did not previously have such a function. This ability helps people in dealing with unpredictable problems by using existing experiences (Liang et al., 2012).
Design Performance (D_4)	Customer Acceptance (c_{41})	Technology acceptance means an individual's psychological state toward his or her voluntary use of a particular technology (Gattiker, 1984).
	Financial Performance (c_{42})	Griffin and Page (1993) proposed the financial performance measure to include break-even time, attain margin goals, attain profitability goals, and IRR/ROI. Later, Berman proposed that financial performance is operationally defined as return on assets (ROA), computed as the ratio of operating income to total assets (Berman, Wicks, Kotha, & Jones, 1999).
	Product Performance (c_{43})	Product performance is a measure of the success of the system developed during the development project (Wallace, Keil, & Rai, 2004). Product performance is a measure of functional aspects of the product (Osteras, Murthy, & Rausand, 2006). To the extent that product performance is more than the sum of component performance or technical specifications, firms need to worry about integrity and thus about integration (Clark & Fujimoto, 1991).
	Program Performance (c_{44})	Programs can be defined as collections of related projects (Wysocki, 2013). PMBOK defined a project as a temporary endeavor undertaken to create a unique product, service, or result (Project Management Institute, 2008). Griffin and Page (1993) proposed that the key to understanding a firm's position vis-a-vis new product development is being able to measure the "success," or alternatively "failure," of individual products and overall development programs.
	Firm Performance (c_{45})	Design is essentially the application of human creativity to a purpose—to create products, services, buildings, organizations and environments that meet people's needs; firms that manage design effectively and efficiently attain better performance than those that do not.

RESEARCH METHOD

To construct the analytic framework for deriving factors to evaluate the curriculum that will enhance the new product development imagination capability, this research first reviewed the related research works of social psychology and literature. Next, the DEMATEL method was employed to establish the causal relationships. Then, the DNP was applied to derive the influence weights based on the experts' perspectives. Finally, the correlations between the criteria as well as the courses were derived using the GRA. In summary, the assessment model consists of four main steps: (1) deriving the requirement by literature review; (2) structuring the causal relationship based on experts' opinions by using the DEMATEL; (3) deriving the weights versus each criterion by using the DNP; and (4) deriving the grey relationships between the evaluation criteria and the courses.

Modified Delphi Method

The Delphi method was designed by Dalkey and Helmer (1963). After the Delphi method, Murry and Hammons (1995) tried to identify issues and problems that were collected from a group of technology education professionals using the Modified-Delphi Technique. The modified Delphi simplified the step of conducting the first round of a survey and replaced the conventionally adopted open style survey (Sung, 2001). The purpose of the modified Delphi method is to save time, and the experts can focus on research themes, eliminating the need for speculation on the open questionnaire, and to improve the response of the main topic (Y. S. Lee, Huang., & Hsu, 2008; Sung, 2001). In this research, the modified Delphi method was used to summarize the opinions of experts. Those criteria recognized by over two third of experts served as the criteria for evaluating the courses.

The DNP

The DNP, the DEMATEL technique combining with ANP, was proposed by Tzeng (C.-H. Liu, Tzeng, & Lee, 2012). The DEMATEL technique was developed by the Battelle Geneva Institute: (1) to analyze complex "real world problems" dealing mainly with interactive map-model techniques (Gabus & Fontela, 1972); and (2) to evaluate qualitative and factor-linked aspects of societal problems. The DNP advanced the traditional decision-making framework by manipulating the DEMATEL and the ANP individually, in that a single round of survey of experts' opinions would be enough to resolve a decision-making problem. In comparison to the traditional approach consisting of two rounds of expert opinion surveys, the DNP actually eased the survey procedure. The DEMATEL technique was developed with the belief that the pioneering and proper use of scientific research methods could help to illuminate specific and intertwined phenomena and contribute to the recognition of practical solutions through a hierarchical structure. The DEMATEL technique was developed with the belief that the pioneering and proper use of scientific research methods could help to illuminate specific and intertwined phenomena and contribute to the recognition of practical solutions through a hierarchical structure. DEMATEL has been successfully applied in many situations such as e-business model definitions (Huang & Shyu, 2006; Huang, Tzeng, & Ho, 2010), policy definitions (C.-Y. Huang, J. Z. Shyu, & G. H. Tzeng, 2007), global manufacturing system optimization (Tzeng & Huang, 2012), technology adoption (Huang & Kao, 2012, 2015; Huang, Kao, Wu, & Tzeng, 2013), provider selection (Liao, Wu, Huang, Kao, & Lee, 2014), etc. The ANP is a general form of the analytic hierarchy process (AHP) (Saaty, 1980) which has been used in multi criteria decision making (MCDM) based researches; such ANP based research can derive weights corresponding to each criteria by releasing the restriction of the hierarchical structure defined in the Analytic Hierarchical Process (AHP). The detailed procedures of the DEMATEL method and the DNP method will be introduced in Appendices A and B.

The GRA Method

Since Deng proposed grey theory in 1982 (Julong, 1989), related models have been developed and applied to MCDM problems. Similar to the fuzzy set theory, the grey theory is a feasible mathematical means used to deal with systems analysis characterized by poor information. Fields covered by the grey theory include systems analysis, data processing, modeling, prediction, decision-making and control. The GRA is used to determine the relationship between two sequences of stochastic data in a grey system. The procedure bears some similarity to pattern recognition technology. One sequence of data is called the "reference pattern" or "reference sequence," and the correlation of the other sequence to the reference sequence is identified (Deng, 1986; Tzeng & Tasur, 1994). When the grey relational coefficient is conducted, we can then derive the grade of grey relation $\gamma(x_0, x_i)$ between the reference and alternative imagination stimulation courses. The detailed procedure of the GRA method will be introduced in Appendix C.

EMPRICAL STUDY

In this article, the authors summarized the courses, which will stimulate, develop and enhance imagination capabilities in concept development, product planning, and product design. At first, the authors invited experts to summarize possible courses and criteria by using the modified Delphi method. After deriving the possible courses

Table 2. Background of Experts

No.	Education	Expertise	Title	Experiences
1	Ph.D.	Industrial Design	Professor	15
2	Ph.D.	Curriculum Design	Professor	15
3	Master	Multimedia Design	Teacher	6
4	Master	Advertisement Design	Teacher	16
5	Ph.D.	Product Design	Associate Professor	22
6	Master	Multimedia Design	Teacher	24
7	Ph.D.	Multimedia Design	Professor	20
8	Ph.D.	Creativity Research	Professor	40
9	Master	Product Design	Professor	23
10	Ph.D.	Technology Management	Professor	21
11	Ph.D.	Psychology	Assistant Professor	5

and criteria, the authors used DEMATEL to derive the key criteria, establish the decision problem structure, and then used the DNP to derive the weight associated with every aspect and criterion. Finally, the authors used GRA to derive the most important courses. The courses can be used to stimulate, develop, and enhance the imagination capabilities of engineering, design, technology management, and innovation management major students.

Enhance the product commercialization courses

In order to define the curricula for enhancing the capabilities in technology commercialization, this study defined a decision-making framework based on MCDM methods. All the possible criteria for evaluating the methods for stimulating imagination were derived based on experts' opinions. The experts were selected from the engineering design fields of industrial design, product development, multimedia and graphic arts communication, or fields related to imagination or creativity education and research. The experts selected included eight university professors and three teachers from vocational high schools. All the experts have more than five years of work experience. Please refer **Table 2** for the background of the experts.

At first, the possible aspects and criteria (refer to **Table 1**) for evaluating the course modules were derived by using the modified Delphi method introduced in Section "The Modified Delphi Method". According to Takahashi (1993), more than 300 idea generation techniques have been invented around the world (Takahashi, 1993). However, a limited number of methods is popular in the related fields of engineering while other methods are not. Therefore, the methods highly related to product commercialization were derived by using the modified Delphi method based on the experts' opinions. The top 13 methods selected as courses include: TRIZ, product portfolio, QFD, scenario analysis, morphological method, weighted objective method, technology roadmapping, bionics, brainstorming, SCAMPER, objective tree, conjoint analysis, and value engineering. The methods are briefly introduced in **Table 4**.

The Causal Relationships and Weight Derivations by the DNP

After the derivation of aspects, criteria and possible methods, the influence relationships between aspects and criteria as well as the associated weights were derived by using the DNP. The DEMATEL is a powerful approach that can be used to systematically analyze the relationships among the criteria and aspects. After that, the DEMATEL based Network Process (DNP), a weight derivation method which was developed based on the concepts of ANP, can be leveraged to derive the weights versus each criterion and aspect in accordance with reciprocal influence relations.

First, the DEMATEL was introduced to derive the influence relationships between aspects and criteria based on the opinions provided by the 11 experts. The initial direct-relation matrix $\boldsymbol{A}$, the normalized matrix $\boldsymbol{N}$, and the total relations matrix $\boldsymbol{T}$ can be derived by using equations (A1), (A2) and (A3), as well as (A4) respectively (the equations can be found in Appendix A). The influence relationship network derived according to the matrix $\boldsymbol{T}$ is demonstrated in **Figure 1**.

$$\boldsymbol{A}=\begin{bmatrix} 0 & 4.556 & 3.889 & 2.889 \\ 4.000 & 0 & 4.222 & 4.222 \\ 3.556 & 3.889 & 0 & 4.000 \\ 3.111 & 3.667 & 3.778 & 0 \end{bmatrix}$$

$$\boldsymbol{N}=\begin{bmatrix} 0 & 0.366 & 0.313 & 0.232 \\ 0.321 & 0 & 0.339 & 0.339 \\ 0.286 & 0.313 & 0 & 0.321 \\ 0.250 & 0.295 & 0.304 & 0 \end{bmatrix}$$

$$\boldsymbol{T}=\begin{bmatrix} 2.586 & 3.109 & 3.046 & 2.866 \\ 2.998 & 3.027 & 3.246 & 3.106 \\ 2.808 & 3.078 & 2.808 & 2.920 \\ 2.632 & 2.898 & 2.874 & 2.518 \end{bmatrix}$$

To derive the causal relationships, we use equations (A5) and (A6) to derive r_i and c_i, which represent the summation of row and column versus the corresponding criteria and aspects. Subsequently, $(r_i + c_i)$ and $(r_i - c_i)$ can be depicted in **Tables 5** and **6**.

Regarding the causal relationships derived, an aspect or criterion is recognized as a cause if $(r_i - c_i)$ is positive. If the corresponding $(r_i - c_i)$ value is negative, the aspect or criterion can be recognized as an effect. Further, the $(r_i + c_i)$ value stands for the strength of the influences being dispatched and received. For the influence relations between the aspects, according to **Table 5**, the initiating imagination (D_1) and conceiving imagination (D_2) have the highest $(r_i - c_i)$ value compared to the rest of the aspects. That is, these two aspects have significant influences on other aspects. By contrast, the transforming imagination (D_3) and design performance (D_4) have negative values of $(r_i - c_i)$, which means these two aspects are mainly influenced by others.

The causal relationship is demonstrated in **Figure 1**. This illustration demonstrates that the initiating imagination (D_1) affects the design performance (D_4), and has mutual influence relations with the conceiving imagination aspect (D_2). The conceiving imagination (D_2) influences transforming imagination (D_3) and design performance (D_4). Moreover, the conceiving imagination (D_2) influences itself by a feedback relationship.

Table 3. The Modified Delphi Results

No.	Criteria																		
	D_1	D_2	D_3	D_4	c_{11}	c_{12}	c_{13}	c_{21}	c_{22}	c_{23}	c_{24}	c_{25}	c_{31}	c_{32}	c_{41}	c_{42}	c_{43}	c_{44}	c_{45}
1	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree
2	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Disagree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree
3	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree
4	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree
5	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree
6	Agree	Disagree	Agree	Disagree	Agree	Agree	Disagree	Agree	Disagree	Agree	Agree	Disagree	Agree	Agree	Agree	Agree	Disagree	Agree	Agree
7	Disagree	Disagree	Agree	Disagree	Agree	Agree	Disagree	Agree	Disagree	Agree	Agree	Agree	Agree	Agree	Agree	Disagree	Agree	Disagree	Agree
8	Agree	Agree	Agree	Agree	Agree	Disagree	Disagree	Disagree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree
9	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree
10	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree
11	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree
Agree	10	9	11	9	11	10	8	10	8	11	11	10	11	11	11	10	10	10	11
Disagree	1	2	0	2	0	1	3	1	3	0	0	1	0	0	0	1	1	1	0
Agree%	90.91%	81.28%	100.00%	81.28%	100.00%	90.91%	72.73%	90.91%	72.73%	100.00%	100.00%	90.91%	100.00%	100.00%	100.00%	90.91%	90.91%	90.91%	100.00%
Disagree%	9.09%	18.18%	0.00%	18.18%	0.00%	9.09%	27.27%	9.09%	27.27%	0.00%	0.00%	9.09%	0.00%	0.00%	0.00%	9.09%	9.09%	9.09%	0.00%

Table 4. Course Modules for Stimulating Imagination Capability

Method	Descriptions
TRIZ (s_1)	TRIZ is a Russian acronym, and its English translation is Theory of Incentive Problem Solving (TIPS). TRIZ helps to analyze problems and pinpoint contradictions, which are later divided into two categories, physical and technical. Different solutions will then be sought.
New Product Portfolio (s_2)	Portfolio management treats R&D investments much like a fund manager in the stock market treats financial investments; it deals with issues such as maximizing the value of the portfolio, hence return on R&D spending; an appropriately balanced portfolio; and a portfolio investment strategy that is aligned with the company's overall business strategy (Cooper, Edgett, & Kleinschmidt, 2001).
QFD (s_3)	The QFD is an integrated planning method that can assure and improve the alignment of elements of design processes with the requirements of customers, as well as it is a managerial philosophy that can help enhance the organizational and managing effects (Yang, Wang, Dulaimi, & Low, 2003). Especially, QFD employs a cross-functional team to plan and design new or improved products or services through a structured and well-documented framework (Karsak, Sozer, & Alptekin, 2003).
Scenario Analysis (s_4)	Scenario development can serve as an aid to planning is focused on developing alternative visions of the future. Visioning exercises typically look farther into the future than other futures methods. Scenario planning has proven to be a disciplined method for imagining possible futures in which decisions may be played out (Schoemaker, 1995), and a powerful tool for asking "what if" questions to explore the consequences of uncertainty.
Morphological Method (s_5)	The morphological method in image processing (Kimori, 2013), which is often used to extract image component, can be used as a scale-dependent roughness measure of gridded DEMs. Morphological methods control the ranges of the local spatial regions by the size of a known shape called structuring element (SE).
Weighted Objective Method (s_6)	The weighted objective method compare the utility values of alternative design proposals, on the basis of performance against differential weighted objectives (Sapuan, Maleque, Hameedullah, Suddin, & Ismail, 2005). In this method, the design objectives were listed and ranked. Relative weight was listed to the objectives; an alternative is to assign relative weight at different levels of an objective tree, so that all weight sum to 1.0; performance parameter or utility values for each objective were established (Sapuan et al., 2005).
Technology Roadmapping (s_7)	A technology roadmap is "a technology planning process based on market needs, which identifies the technological alternatives necessary to satisfy the market requirements or the product requirements and facilitates the selection and development of these technologies (Garcia & Bray, 1997). In addition, it expresses the performance target required for the future and the R&D activities or technology alternatives needed to meet these targets on a temporal axis.
Bionics (s_8)	Bionics is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology (Grzesiak, Becker, & Verl, 2011).
Brain Storming (s_9)	Brainstorming as an effective means of enhancing the quantity and quality of ideas generated in group settings. Typical brainstorming instructions prompt group members to generate as many ideas as possible, to evaluate uncritically their own ideas before expressing them, to evaluate uncritically other people's ideas when they are expressed, and to improve or combine ideas already suggested (Osborn, 1953).
SCAMPER (s_{10})	Eberle (1996) originated the SCAMPER model as a way of remembering major factors and processes involved in any aspect of creativity (Gladding & Henderson, 2000). The changes that SCAMPER stands for are Substitute, Combine, Adapt, Modify, Put to another use, Eliminate and Reverse (Serrat, 2009).
Objective Tree (s_{11})	According to Pahl and Beitz (1988), the objective tree method offers a clear format for the higher-level objective and the sub-objectives, which is offers a clear format for the higher-level objective and the sub-objectives, which is useful in evaluating goal strategies. The principal or most important key construct occupies the top level. The variables or factors of each key construct occupy the second level. Moreover, the measurement of each variable or factor is on the third level. Finally, the fourth level is for comparing different alternatives.
Conjoint Analysis (s_{12})	Conjoint analysis is grounded in both psychology and economics (McFadden, 1986). Conjoint analysis considers all possible combinations of attribute levels. Conjoint analysis belongs to a class of multivariate research techniques that use participants' choices (e.g., rankings for a set of product configurations) to estimate the underlying attribute relationships, enabling researchers to study preferences (Green & Srinivasan, 1978).
Value Engineering (s_{13})	Value engineering is an organized/systematic approach directed at analyzing the function of systems, equipment, facilities, services, and supplies for the purpose of achieving their essential functions at the lowest life-cycle cost consistent with required performance, reliability, quality, and safety (Kelly, Male, & Graham, 2014).

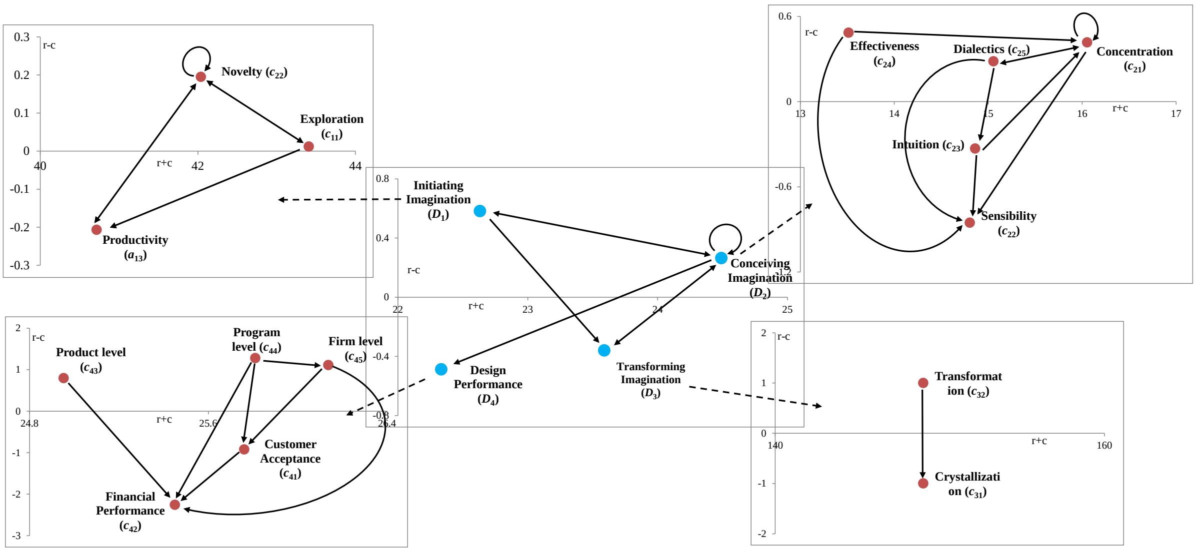

Figure 1. The Influence Relationships Network

Table 6 demonstrates $(r_i + c_i)$ and $(r_i - c_i)$ values versus each criterion. According to **Table 6**, the $(r_i - c_i)$ value of novelty (c_{12}) is the highest in the initiating imagination (D_1) aspect. In the conceiving imagination (D_2) aspect, effectiveness (c_{24}), concentration (c_{21}), and dialectics (c_{25}) are the criteria with the highest positive $(r_i - c_i)$ values. In the transforming imagination (D_3) aspect, transformation (c_{32}) has the highest $(r_i - c_i)$ value. In the design performance (D_4) aspect, program performance (c_{44}) and firm performance (c_{45}) have the highest $(r_i - c_i)$ values. Specifically, in each aspect, the above-mentioned criteria with positive $(r_i - c_i)$ values generate significant effects on other criteria belonging to that aspect.

Based on the influence relation derived by DEMATEL, we further derived the weights corresponding to the aspects and criteria based on the DNP introduced in Appendix B. The weights can be derived by considering both local weights derived from the influence relations in each aspect, and the corresponding aspect weights derived from the influence relationships between aspects. Therefore, the global weight stands for the real influence weights derived from the local weight. The global weight can be regarded as a priority indicator for ranking these aspects and criteria. The importance versus these aspects and criteria can thus be evaluated and ranked. According to the analytic results derived in **Table 7**, conceiving imagination (D_2) is the most important aspect versus other aspects. Initiating imagination (D_1) is the least important aspect.

Based on the influence weights versus each aspect and criterion, for the initiating imagination (D_1) aspect, the influential weights versus the criteria can be ranked as exploration (c_{11}) $\succ$ novelty (c_{12}) $\succ$ productivity (c_{13}). Likewise, the order of influential weights versus the criteria in the conceiving imagination (D_2) aspect can be ranked as concentration (c_{21}) $\succ$ sensibility (c_{22}) $\succ$ intuition (c_{23}) $\succ$ dialectics (c_{25}) $\succ$ effectiveness (c_{24}). Subsequently, the order of influential weights versus the criteria in the transforming imagination (D_3) aspect can be ranked as transformation (c_{32}) $\succ$ crystallization (c_{31}) . Finally, the order of influential weights versus the criteria in the design performance (D_4) aspect is financial performance (c_{42}) $\succ$ customer acceptance (c_{41}) $\succ$ firm performance (c_{45}) $\succ$ program performance (c_{44}) $\succ$ product performance (c_{43}).

Table 5. $(r_i + c_i)$ and $(r_i - c_i)$ versus each aspect

Aspects	r_i	c_i	$r_i + c_i$	$r_i - c_i$
Initiating Imagination (D_1)	11.607	11.025	22.632	0.583
Conceiving Imagination (D_2)	12.378	12.113	24.491	0.265
Transforming Imagination (D_3)	11.615	11.974	23.589	-0.359
Design Performance (D_4)	10.923	11.411	22.334	-0.488

Table 6. $(r_i + c_i)$ and $(r_i - c_i)$ versus each criterion

Criteria	r_i	c_i	$r_i + c_i$	$r_i - c_i$
Exploration (c_{11})	21.710	21.698	43.409	0.012
Novelty (c_{12})	21.117	20.922	42.039	0.195
Productivity (c_{13})	20.255	20.462	40.717	-0.207
Concentration (c_{21})	8.235	7.819	16.054	0.416
Sensibility (c_{22})	6.976	7.829	14.805	-0.853
Intuition (c_{23})	7.266	7.596	14.862	-0.331
Effectiveness (c_{24})	7.000	6.515	13.515	0.485
Dialectics (c_{25})	7.670	7.387	15.057	0.283
Crystallization (c_{31})	74.000	75.000	149.000	-1.000
Transformation (c_{32})	75.000	74.000	149.000	1.000
Customer Acceptance (c_{41})	12.419	13.342	25.761	-0.923
Financial Performance (c_{42})	11.596	13.854	25.451	-2.258
Product level (c_{43})	12.874	12.079	24.953	0.796
Program level (c_{44})	13.543	12.267	25.810	1.276
Firm level (c_{45})	13.623	12.514	26.137	1.110

Table 7. The Influence Weights versus Each Aspect and Criterion

Aspect	Weight	Rank	Criteria	Weight	Rank	Global weights
Initiating Imagination (D_1)	0.237	4	Exploration (c_{11})	0.344	1	0.082
			Novelty (c_{12})	0.332	2	0.079
			Productivity (c_{13})	0.324	3	0.077
Conceiving Imagination (D_2)	0.260	1	Concentration (c_{21})	0.211	1	0.055
			Sensibility (c_{22})	0.210	2	0.055
			Intuition (c_{23})	0.204	3	0.053
			Effectiveness (c_{24})	0.176	5	0.046
			Dialectics (c_{25})	0.199	4	0.052
Transforming Imagination (D_3)	0.257	2	Crystallization (c_{31})	0.503	1	0.129
			Transformation (c_{32})	0.497	2	0.128
Design Performance (D_4)	0.245	3	Customer Acceptance (c_{41})	0.208	2	0.051
			Financial Performance (c_{42})	0.216	1	0.053
			Product Performance (c_{43})	0.189	5	0.046
			Program Performance (c_{44})	0.192	4	0.047
			Firm Performance (c_{45})	0.196	3	0.048

Table 8. The Grey Relation Matrix, Grey Grade, and Rank

Criteria / Methods	Symbol	c_{11}	c_{12}	c_{13}	c_{21}	c_{22}	c_{23}	c_{24}	c_{25}	c_{31}	c_{32}	c_{41}	c_{42}	c_{43}	c_{44}	c_{45}	Grade	Rank
TRIZ	s_1	0.080	0.085	0.082	0.027	0.054	0.026	0.015	0.031	0.128	0.126	0.017	0.017	0.015	0.046	0.016	0.767	2
Product Portfolio Theory	s_2	0.027	0.028	0.027	0.027	0.027	0.035	0.015	0.018	0.128	0.126	0.034	0.052	0.046	0.046	0.047	0.683	4
Quality Function Deployment (QFD)	s_3	0.080	0.057	0.082	0.054	0.054	0.053	0.045	0.051	0.128	0.126	0.050	0.026	0.046	0.046	0.047	0.946	1
Scenario Analysis	s_4	0.080	0.043	0.027	0.027	0.036	0.026	0.045	0.031	0.128	0.042	0.050	0.026	0.015	0.046	0.016	0.640	6
Morphological Method	s_5	0.040	0.043	0.082	0.027	0.054	0.035	0.023	0.018	0.128	0.042	0.025	0.026	0.023	0.023	0.024	0.612	8
The weighted Objective Method	s_6	0.040	0.043	0.082	0.054	0.027	0.026	0.015	0.018	0.128	0.042	0.025	0.026	0.023	0.031	0.024	0.604	9
Technology Roadmapping	s_7	0.027	0.028	0.082	0.054	0.054	0.018	0.015	0.018	0.128	0.042	0.050	0.035	0.030	0.046	0.047	0.675	5
Bionics	s_8	0.080	0.085	0.041	0.018	0.018	0.018	0.045	0.018	0.043	0.042	0.017	0.017	0.015	0.016	0.016	0.488	12
Brain Storming	s_9	0.080	0.085	0.041	0.027	0.022	0.053	0.023	0.031	0.064	0.042	0.025	0.017	0.023	0.023	0.024	0.580	11
SCAMPER	s_{10}	0.080	0.043	0.082	0.054	0.054	0.053	0.015	0.018	0.128	0.042	0.050	0.017	0.023	0.023	0.024	0.706	3
Objective Tree	s_{11}	0.054	0.028	0.027	0.027	0.018	0.026	0.015	0.018	0.043	0.042	0.025	0.017	0.015	0.023	0.016	0.395	13
Conjoint Analysis	s_{12}	0.054	0.043	0.055	0.036	0.036	0.035	0.015	0.018	0.128	0.042	0.034	0.035	0.030	0.031	0.032	0.622	7
Value Engineering Method	s_{13}	0.040	0.028	0.041	0.054	0.054	0.026	0.015	0.018	0.128	0.063	0.017	0.035	0.015	0.023	0.024	0.581	10

Determine the Module Courses by Using Grey Relation

Finally, the author introduced the GRA (refer to Appendix C) to derive the module courses which will be most suitable for stimulating, developing and enhancing imagination capabilities in commercialization of technology. First of all, 13 courses and 15 capabilities were filled into the grey relation matrix based on equation (C1). Then, the DNP derived in Section "The Causal Relationships and Weight Derivations by the DNP" was introduced into the GRA based on equation (C4). The grey grades versus each course can be derived accordingly. According to the analytic results, QFD (s_3), TRIZ (s_1), SCAMPER (s_{10}), and the New Product Portfolio Method (s_2) are the courses with the highest grey relationships to the engineering imagination capabilities. The results are demonstrated in **Table 8**.

DISCUSSION

In the following section, the authors will discuss the rationalities of influence relationships and the derivations of the imagination stimulation courses. Meanwhile, the consistency between the empirical study and past research will be checked and discussed. Further, the differences between the courses selected by considering the new product development success or failure aspect will be discussed to demonstrate the importance of considering the new product development success aspect. Limitations as well as future research possibilities will also be discussed in the final part of this Discussion Section.

The Rationality of the Influence Relationships

In this sub-section, the rationality of the influence relationships will be discussed. For the influence relationships derived by using the DNP, conceiving imagination (D_2) serves as the driver for influencing other aspects. The conceiving imagination (D_2) is influenced by both aspects, which include the initiating imagination (D_1) aspect and the transforming imagination (D_3) aspect. Furthermore, the conceiving imagination (D_2) also served as a mediator between (1) the initiating imagination (D_1) aspect and the design performance (D_4) aspect, as well as (2) the initiating imagination (D_1) aspect and the transforming imagination (D_3) aspect. The influence relationships derived are consistent with the perspectives from Gaut (2003), who argued that the conceiving imagination should be a trigger that would generate positive influences on other aspects of imagination and should be the vehicle of active creativity. Further, the analytic result is also consistent with the research results found by Hsu, Liang, and Chang (2014): both initiating and transforming imagination would generate the mental images formed and shaped by conceiving imagination. As mentioned above, we found that the conceiving imagination (D_2) influences itself through the feedback loop(s). This result demonstrates the self-enforcing effect of the conceiving imagination (D_2) aspect. For instance, if people use more intuitive representations, their conceiving imagination can last longer (Townsend, 2003). This analytic result further demonstrates that the conceiving imagination has significant influences on design performances. Tamer Cavusgil, Calantone, and Zhao (2003) argued that imagination and creativity are the key factors for innovation outcomes and performances. Employees will generate better job performance by using their imagination and creativity. In the research on salespersons, Barker (1999) found that a salesperson would achieve better performance if his/her creativity and imagination were higher. Further, according to the analytic results by Barker, design performance was one of the measurements of creativity and imagination. Thus, the analytic result of this research is consistent with past studies. For above reasons and findings, practitioners can take these research results into account for the imagination cultivation.

Based on the derived influence relationships, there are several possible strategies to enhance imagination. (1) The initiating imagination (D_1) and conceiving imagination (D_2) influence each other. It means that they can enhance each other, the transforming imagination (D_3) will then acquire essential elevation in performance; (2) The design performance (D_4) will be significantly elevated through the improvements of the initiating imagination (D_1) and conceiving imagination (D_2); and (3) all of the imagination enhancement strategies within each aspect are demonstrated as below (see **Table 9**) and will also be discussed as below. By these improving strategies, we can understand in the future how to strengthen which imagination capabilities so that the engineering imagination capability in technology commercialization can have a significant elevation.

Table 9. Imagination Enhancement Strategies

Aspect	Strategy
Aspects	$D_1 \rightarrow D_2 \rightarrow D_3$
	$D_1 \rightarrow D_2 \rightarrow D_4$
	$D_2 \rightarrow D_1 \rightarrow D_3$
Initiating Imagination (D_1)	$c_{12} \rightarrow c_{11} \rightarrow c_{13}$
	$c_{11} \rightarrow c_{12} \rightarrow c_{13}$
	$c_{25} \rightarrow c_{21} \rightarrow c_{22}$
Conceiving imagination (D_2)	$c_{24} \rightarrow c_{21} \rightarrow c_{25} \rightarrow c_{23} \rightarrow c_{22}$
	$c_{25} \rightarrow c_{21} \rightarrow c_{22}$
Transforming Imagination (D_3)	$c_{32} \rightarrow c_{31}$
Design Performance (D_4)	$c_{44} \rightarrow c_{45} \rightarrow c_{41} \rightarrow c_{42}$
	$c_{44} \rightarrow c_{41} \rightarrow c_{42}$

We further discuss the influence relationships of criteria within each aspect. For the initiating imagination (D_1) aspect, we found that novelty (c_{12}) directly influences both exploration (c_{11}) and productivity (c_{13}). Exploration (c_{11}) has the direct influences on novelty (c_{12}) and productivity (c_{13}). From the perspective of enhancing initiating imagination, imagination capabilities can be enhanced by following two strategies. In the first strategy, novelty (c_{12}) influences exploration (c_{11}); exploration (c_{11}) further influences productivity (c_{13}). The causal relationships can be expressed as $c_{12} \rightarrow c_{11} \rightarrow c_{13}$. In the second strategy, exploration (c_{11}) influences novelty (c_{12}) while novelty (c_{12}) can further influence productivity (c_{13}). The causal relationships can be expressed as $c_{11} \rightarrow c_{12} \rightarrow c_{13}$.

In the conceiving imagination (D_2) aspect, concentration (c_{21}) influences dialectics (c_{25}), intuition (c_{23}), and sensibility (c_{22}) significantly. Further, based on the results derived by DEMATEL, effectiveness (c_{24}), dialectics (c_{25}), and concentration (c_{21}) will generate significant influence on other criteria. Imagination capabilities can be enhanced by introducing two strategies. In the first strategy, effectiveness (c_{24}) influences concentration (c_{21}); concentration (c_{21}) influences dialectics (c_{25}); dialectic (c_{25}) influences intuition (c_{23}); and then intuition (c_{23}) influences sensibility (c_{22}). The causal relationships can be expressed as $c_{24} \rightarrow c_{21} \rightarrow c_{25} \rightarrow c_{23} \rightarrow c_{22}$. In the second strategy, dialectics (c_{25}) influences concentration (c_{21}); and concentration (c_{21}) influences sensibility (c_{22}). The causal relationships can be expressed as $c_{25} \rightarrow c_{21} \rightarrow c_{22}$. In the transforming imagination (D_3) aspect, crystallization (c_{32}) influences transformation (c_{31}) directly. The imagination enhancement strategy can be expressed as $c_{32} \rightarrow c_{31}$.

Finally, in the design performance (D_4) aspect, according to the analytic results derived by DEMATEL in Section "The Causal Relationships and Weight Derivations by the DNP", the criteria including program performance (c_{44}), firm performance (c_{45}), and product performance (c_{43}) are categorized as cause criteria that can influence others. The customer acceptance (c_{41}) and financial performance (c_{42}) criteria are categorized as the effect criteria, which are influenced by the cause criteria. Two imagination capability enhancement strategies were derived. In the first strategy, program performance (c_{44}) influences firm performance (c_{45}); firm performance (c_{45}) influences customer acceptance (c_{41}); and then, customer acceptance (c_{41}) influences financial performance (c_{42}). The causal relationships can be expressed as $c_{44} \rightarrow c_{45} \rightarrow c_{41} \rightarrow c_{42}$. Another enhancing strategy in design performance aspects describes program performance (c_{44}) influences customer acceptance (c_{41}) and then, customer acceptance (c_{41}) influences financial performance (c_{42}). The causal relationships can be expressed as $c_{44} \rightarrow c_{41} \rightarrow c_{42}$. The above-mentioned imagination enhancement strategies are clear and easy for real world applications. Based on the above derived results of improving strategies, it will enable students to elevate their imagination in engineering design in the future.

In addition to the causal networks' derivation and analysis, we derived the influence weights by the DNP method. Concerning the aspect weights, the conceiving imagination (D_2) aspect is the one with the highest influence weight (0.260). The weights associated with the other aspects, transforming imagination (D_3), design performance (D_4), and initiating imagination (D_1), are 0.257, 0.245, and 0.237, respectively. This result demonstrates the dominant role of conceiving imagination on imagination enhancement for technology commercialization. The analytic result is consistent with the results by previous researchers' works (Hsu et al., 2014; J.-S. Lin, Liang, Chang, & Liang, 2015).

In the initiating imagination (D_1) aspect, exploration (c_{11}) has the highest value (0.344), which implies its relative importance in comparison with other important criteria in the initiating imagination aspect. For product design, the ability to explore and seek the unknown is always indispensable (Colello, 2007). Therefore, enhancing the exploration capability should always be emphasized by courses so that the corresponding capabilities of students can be enhanced. Further, in the conceiving imagination (D_2) aspect, the weights associated with concentration (c_{21}) and sensibility (c_{22}) are 0.211 and 0.210, respectively. These two criteria should be noticeable. Through the causal networks, imagination enhancement strategies have already demonstrated how intuition and sensibility can be enhanced to stimulate, develop and enhance students' imagination capabilities. In the transforming imagination (D_3) aspect, the weight (0.503) associated with crystallization (c_{32}) is higher than that of transformation (c_{31}), which is 0.497. Finally, in the design performance aspect, the influential weights of financial performance, customer acceptance, firm performance, program performance, and product performance are 0.216, 0.208, 0.196, 0.192, and 0.189, respectively. In order to enhance the financial performance (c_{42}) and customer acceptance (c_{41}) from the causal networks, the strategies demonstrated in the form of causal relationships as of $c_{44} \rightarrow c_{45} \rightarrow c_{41} \rightarrow c_{42}$ or $c_{44} \rightarrow c_{41} \rightarrow c_{42}$ can be adopted. The DNP result in design performance corresponding to its causal relationship, the finding implies that customer acceptance (c_{41}) and financial performance (c_{42}) should be crucial than other criteria. In the real world, designing products, financial issues and customer acceptance are often essential concepts (Griffin & Page, 1993). Therefore, these two criteria are recognized as more important in comparison to other criteria in the aspect.

The Rationale for Selecting the Methods for Improving Imagination

Based on the empirical study results, the methods that include QFD (s_3), TRIZ (s_1), SCAMPER (s_{10}), and the New Product Portfolio Method (s_2) are the methods with the highest relationships to the engineering imagination capabilities. In the following section, the rationale for selecting the methods will be discussed. Meanwhile, the consistency between the empirical study results and past research will be discussed.

QFD

For the top-ranking course, the QFD was ranked as the number-one alternative because the QFD method outperforms other methods in almost all aspects, including creative imagination, reproductive imagination and product development success. As the QFD method can fulfill requirements such as customers' satisfaction with products (c_{41}), good responses of product use by customers (c_{43}), tasks execution and development meet with top directors' requests (c_{44}) and product design and development achieve the firms' goal (c_{45}), the method was recognized as the best one to enhance the technology commercialization imagination capability. The analytic results derived based on experts' opinions are consistent with past research.

The QFD outperformed all other methods in all criteria and is related to exploration (c_{11}) and productivity (c_{13}). For exploration (c_1) of the unknown areas of knowledge and experience, the QFD can also facilitate continuous product improvement with emphasis on the impact of organization learning on innovation (Yang et al., 2003). According to Garvin 1993 (Garvin, 1985), this organizational learning is associated with an organization's ability to explore the unknown and to identify and pursue novel solutions (Ahire & Dreyfus, 2000). For novelty (c_{12}), albeit the QFD outperformed most methods, the experts' opinions were that TRIZ, Bionics, and Brainstorming could bring more novel ideas

For productivity, Politis (2005) has verified the positive correlations between each of the QFD constructs (i.e. QFD strategic planning, customer and market focus, QFD information and analysis, human resources focus on QFD, top management commitment to QFD, QFD training to supervisors, and worker-supervisor collaboration in QFD efforts) will be positively related to productivity.

In the reproductive imagination aspect, from the aspect of crystallization (c_{31}), the QFD helps to analyze customer's requirements systematically and transform them properly into the appropriate product features (Büyüközkan, Feyzioğlu, & Ruan, 2007). The method outperforms other methods in expressing abstract ideas by using concrete examples. From the aspect of transformation, QFD can transfer ideas to multiple fields of tasks. According to Bossert (1991), QFD is a method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts.

Finally, in the product development success aspect, for fulfilling customers’ satisfaction with products (c_{41}), S. Lee and Sai On Ko (2000) argued that the main goal of QFD is to increase customers' satisfaction by improving their own quality and by exciting the customer through innovation. Further, Juan et al. mentioned that the QFD was a quality management method for converting the customer's needs into design (Juan, Perng, Castro-Lacouture, & Lu, 2009). For good responses of product use by customers (c_{43}), Griffin and Hauser (1993) mentioned that the QFD was a total-quality-management process in which the “voice of the customer” was deployed throughout the R&D, engineering, and manufacturing stages of product development. Ermer (1995) argued that the QFD was a better tool to understand customers' needs. Many other scholars have also reached the same conclusion that the QFD could bring customers’ voices, no matter good response (c_{43}) or bad mouths into the organization.

TRIZ

TRIZ was recognized as a powerful systematic innovation tool. For some, TRIZ is a powerful design methodology; others use it as creative imagination booster and a few others use it as a tool to overcome deadlock situations faced in technical progress (Kwatra & Salamatov, 2012). In this research, TRIZ was also recognized as a useful tool for stimulating imagination capability for commercializing a technology from the first and the third aspects.

For the first creativity imagination aspect, TRIZ outperformed other methods in all criteria, including exploration (c_{11}), novelty (c_{12}), and productivity (c_{13}). According to Souchkov (2007), the inventive principles of TRIZ can serve as triggers to activate our creative imagination. The entire problem-solving process being guided by TRIZ tools directs the problem solver to explore solutions in directions that have previously been proven successfully (Chai, Zhang, & Tan, 2005). Therefore, TRIZ can serve as a feasible and efficient tool for exploring unknown areas of knowledge and experience, which have already been uncovered and proven successfully in other fields (c_{11}). For the novelty (c_{12}) criterion, the viewpoint is consistent with past research. Okudan, Ogot, and Shirwaiker (2006) reported that the introduction of TRIZ to first-year engineering students helped design teams to generate more feasible design concepts, and more unique designs that students who did not learn TRIZ. TRIZ has been recognized by scholars as a tool in enhancing productivity. The experts’ opinions further supported the viewpoint. Ruchti and Livotov (2001) argued that TRIZ-based thinking methods can improve both the efficiency and effectiveness of decision making in organizations. Schweizer (2002) argued that the more one uses TRIZ, the more one will integrate TRIZ methodology with other problem solving methodologies, enhancing their effectiveness. According to Savransky (2000), many Fortune 500 companies have cited a phenomenal increase in productivity, and they credit TRIZ for the breakthrough ideas and quality solutions to tough engineering problems as fueling that increase. Apparently, TRIZ also has been widely recognized by scholars as a tool to enhance effectiveness and further productivity.

For the third aspect, crystallization or expressing abstract ideas by using concrete examples (c_{31}), according to a comparison of TRIZ with other innovation methodologies, including brain storming, 5W1H, bionic association, combination method, reverse innovation, and technology transplant, translating an idea into practice is easy for TRIZ due to its scientific characteristics (Gao, Huang, & Ma, 2005). The summarization by Gao et al. (2005) is consistent with the results of our research. Further, TRIZ outperformed other tools in cross industry innovations (c_{32}). The analytic results are consistent with past research. Chai et al. (2005) observed that through the analysis of more than 2 million patents, a number of innovation patterns and laws of ideality were identified by Altshuller, Shulyak, and Rodman (1997), the inventors of TRIZ. TRIZ reveals the following characteristics: problems and solutions repeated across industries and sciences; patterns of technical evolution repeated across industries and sciences; and innovations using scientific effects outside the field where they were developed (Chai et al., 2005). According to Tan, Ma, Yang, and Sun (2008), the obstacle for idea generation for designers in fuzzy front end (FFE) is the difficulty in applying knowledge in different fields. TRIZ and computer-aided innovation systems (CAIs) which are TRIZ-based software systems with a knowledge base, provide a framework for knowledge application in different fields. The analytic result is consistent with the work by Enkel and Gassmann (2010): mostly, cross-industry innovation leads to technological breakthroughs; this could be because technological patents or function descriptions are easier to find through patent analysis or problem-solving methods like TRIZ than solutions leading to market breakthroughs. Apparently, TRIZ can serve as an efficient tool to innovate cross industries.

Finally, the reason about why the TRIZ cannot be ranked by experts as the number-one method showed that TRIZ is comparatively weaker in real-world applications. One of the most significant drawbacks of TRIZ is the weak application in achieving design success (D_4) and the corresponding criteria ($c_{41}, c_{42}, \ldots, c_{45}$) belonging to this aspect. The experts' opinions were consistent with earlier works criticizing the weakness of TRIZ. According to Zlotin et al. (1999), basic TRIZ concepts such as ideality, contradictions and the systems approach were fully applicable to non-technical problems and situations. Analytical tools and the psychological operators were directly applicable and easily modifiable to accommodate non-technical applications, while knowledge-based tools required some process of abstraction and generalization away from their technology-centric origins (Ilevbare, Probert, & Phaal, 2013). Still it is argued by some that if it were applied appropriately, TRIZ would be capable of providing useful outcomes in practically every field (Rutitsky, 2010).

SCAMPER

SCAMPER has widely been recognized by various scholars (Clarkson, 2003; Eberle & Weber, 1990; Mijares-Colmenares, Masten, & Underwood, 1993) as an efficient method for creative imagination development. According to C.-L. Lin, Hong, Hwang, and Lin (2006), SCAMPER was identified as an applicable technique to processes characterized by knowledge background of participants, high differences among participants, availability of information, democratic process in meeting, constructive dialogues, or need for elaboration of ideas. This is consistent with our analytic result that SCAMPER leads most other methods in the first aspect, creativity (D_1). However, SCAMPER is not without limitations and was ranked only in third place due to the comparatively lower grey coefficients in the second aspect, conceiving imagination, in criteria effectiveness (c_{24}) and dialectics (c_{25}) and in the fourth aspect, achieving design success (D_4) and the corresponding criteria ($c_{42}, \ldots, c_{45}$) belonging to this aspect.

According to the Delft Design Guide by Van Boeijen, Daalhuizen, Van Der Schoor, and Zijlstra (2014), the SCAMPER method might suggest that by applying the seven heuristics (Substitute, Combine, Adapt, Modify, Put to another use, Eliminate and Reverse), creativity is guaranteed. This is not the case, as a lot depends upon the designer use of the heuristics. Therefore, the SCAMPER method is not suitable for untrained designers. The observation is consistent with the analytic results that SCAMPER was ranked lower. Most engineering students or students belonging to other academic fields should be classified as untrained designers. Therefore, unexperienced students lack new ideas, which can lead by intuition (c_{24}), lack of sensibility to help the students imagine by arousing personal feelings (c_{25}). Of course, the students without experience are not flexible in their thinking and can transfer ideas to multiple fields of tasks (c_{32}). Finally, some shortages of SCAMPER, summarized by Gladding and Henderson (2000), include the mechanical usage, shortsighted and uncreative users, as well as the inhibition of the flow of creativity of users because they became dependent on SCAMPER or other shortcuts to fostering change, thereby failing to draw on their own experience, expertise, or intuition. These disadvantages may hinder the users' imagination capability, creativity, the design performance (D_4) and the successful commercialization of technology.

Utilizations of the Finding to Practical Implications

In this sub-Section, substantial suggestions for practitioners based on the findings will be summarized based on both the influence relations and the Grey relationships being derived and discussed in Sections "The Causal Relationships and Weight Derivations by the DNP", "Determine the Module Courses by Using Grey Relation" and Sections "The Rationality of the Influence Relationships", "The Rationale for Selecting the Methods for Improving Imagination".

At first, based on the imagination enhancement strategies being summarized in **Table 9**, for the capabilities belonging to the initiating imagination aspect (D_1), based on the influence relationship $c_{12} \rightarrow c_{11} \rightarrow c_{13}$, we conclude that an enhancement in novelty (c_{12}) can further influence exploration (c_{11}) and then, productivity (c_{13}). Meanwhile, based on $c_{11} \rightarrow c_{12} \rightarrow c_{13}$, an enhancement in exploration (c_{11}) can further influence novelty (c_{12}) and then, productivity (c_{13}). Therefore, students' initiating imagination can be enhanced base on the influence relationships as well as the highly-correlated methods to the capabilities c_{11} and c_{12}. According to results of the Grey relation analysis being demonstrated in **Table 8**, the methods with the highest Grey coefficients with exploration (c_{11}) and novelty (c_{12}) are TRIZ, Bionics and Brain Storming. That is, imagination capabilities of the engineering students who are insufficient in these two capabilities can be enhanced by such methods.

The capabilities belonging to the conceiving imagination aspect (D_2) can be enhanced by the influence relationships $c_{25} \rightarrow c_{21} \rightarrow c_{22}$ and $c_{24} \rightarrow c_{21} \rightarrow c_{25} \rightarrow c_{23} \rightarrow c_{22}$. Therefore, students' initiating imagination can be enhanced base on the influence relationships as well as the highly-correlated methods to the capabilities c_{24} and c_{25}. According to results of the Grey relation analysis being demonstrated in **Table 8**, the methods with the highest Grey coefficients with effectiveness (c_{24}) are QFD, scenario analysis, and Bionics while the methods with higher Grey coefficients with dialectics (c_{25}) are QFD, scenario analysis and brain storming. Engineering students who are insufficient in these two capabilities can be enhanced by these methods.

In the transforming imagination aspect (D_3), engineering students' imagination capabilities can be enhanced by TRIZ, product portfolio theory and the QFD since the three methods have the highest Grey correlation coefficients with the crystallization (c_{32}) capability, which can influence transformation (c_{31}) directly ($c_{32} \rightarrow c_{31}$).

Finally, in the design performance aspect (D_4), the methods which include TRIZ, product portfolio theory, QFD, scenario analysis and technology roadmapping can be used to enhance program Performance (c_{44}), which can further influence other capabilities through the casual relationships, $c_{44} \rightarrow c_{45} \rightarrow c_{41} \rightarrow c_{42}$ and $c_{44} \rightarrow c_{41} \rightarrow c_{42}$.

Hence, in the real-world applications, the engineering students' imagination capabilities can be evaluated based on designs of technology or new product development plans by using the aspects and criteria being summarized in **Table 9**. Based on the evaluation results, the insufficient imagination capabilities can be enhanced by using the methods which are closely related to the capabilities in each causal relationship being discussed in this sub-Section. For example, if the students are asked to design the shell of a portable device (e.g. a mobile phone), and designs are evaluated by experts as being short of transformation (c_{31}) capability, the students can introduce the TRIZ, product portfolio, and the QFD method to enhance the crystallization (c_{32}) capability, and then influence the transformation (c_{31}) capability.

A Comparison between Inclusion versus Exclusion of the Design Performance Aspect and the Derived Courses

Since the authors aim to evaluate the impact of the product development success and failure aspect as well as the corresponding criteria, the aspect and criteria are removed to demonstrate the differences. To demonstrate the differences by using the aspects which have already been verified as feasible by earlier works, (e.g., W.-S. Lin et al., 2014), the authors removed the product development success aspect, and derived the influence relationship between the aspects and criteria, the weights being associated with the aspects and criteria, as well as the grey grades corresponding to the methods that can stimulate the imagination capabilities.

Table 10. Weights being Associated with the Imagination Capabilities

Criteria	c_{11}	c_{12}	c_{13}	c_{21}	c_{22}	c_{23}	c_{24}	c_{25}	c_{31}	c_{32}
Weight	0.080	0.085	0.082	0.054	0.054	0.052	0.045	0.051	0.128	0.126

Table 11. The Grey Relation Matrix, Grey Grade, and Rank

Methods \ Criteria	Symbol	c_{11}	c_{12}	c_{13}	c_{21}	c_{22}	c_{23}	c_{24}	c_{25}	c_{31}	c_{32}	Grade	Rank
TRIZ	s_1	0.0804	0.0852	0.0823	0.0271	0.054	0.0262	0.015	0.0314	0.1277	0.126	0.6553	2
Product Portfolio Theory	s_2	0.0268	0.0284	0.0274	0.0271	0.027	0.035	0.015	0.0178	0.1277	0.126	0.4581	11
Quality Function Deployment (QFD)	s_3	0.0804	0.0568	0.0823	0.0541	0.054	0.0525	0.0451	0.0511	0.1277	0.126	0.7299	1
Scenario Analysis	s_4	0.0804	0.0426	0.0274	0.0271	0.036	0.0262	0.0451	0.0314	0.1277	0.042	0.4859	5
Morphological Method	s_5	0.0402	0.0426	0.0823	0.0271	0.054	0.035	0.0225	0.0178	0.1277	0.042	0.4911	4
The weighted Objective Method	s_6	0.0402	0.0426	0.0823	0.0541	0.027	0.0262	0.015	0.0178	0.1277	0.042	0.4749	6
Technology Roadmapping	s_7	0.0268	0.0284	0.0823	0.0541	0.054	0.0175	0.015	0.0178	0.1277	0.042	0.4655	9
Bionics	s_8	0.0804	0.0852	0.0411	0.018	0.018	0.0175	0.0451	0.0178	0.0426	0.042	0.4077	12
Brain Storming	s_9	0.0804	0.0852	0.0411	0.0271	0.0216	0.0525	0.0225	0.0314	0.0638	0.042	0.4677	7
SCAMPER	s_{10}	0.0804	0.0426	0.0823	0.0541	0.054	0.0525	0.015	0.0178	0.1277	0.042	0.5684	3
Objective Tree	s_{11}	0.0536	0.0284	0.0274	0.0271	0.018	0.0262	0.015	0.0178	0.0426	0.042	0.2981	13
Conjoint Analysis	s_{12}	0.0536	0.0426	0.0548	0.0361	0.036	0.035	0.015	0.0178	0.1277	0.042	0.4606	10
Value Engineering Method	s_{13}	0.0402	0.0284	0.0411	0.0541	0.054	0.0262	0.015	0.0178	0.1277	0.063	0.4676	8

Based on the analytic results, the weights associated with the criteria are shown in the following **Table 10**. According to the grey grades demonstrated in **Table 11**, the courses with the highest grey grades, which include QFD (s_3), TRIZ (s_1), and SCAMPER (s_{10}), are similar. However, the rankings of some methods change significantly (refer **Table 12**). On one hand, the new product portfolio method was downgraded from 4th place to 11th place. The raking of technology roadmapping was also downgraded significantly from 5th place to 9th place. On the other hand, the Morphological Method and the brain storming method were upgraded to 4th place and 7th place, respectively. That means, by considering the aspects that had been recognized as important by earlier research, the methods that had already been recognized by scholars as efficient in enhancing the imagination capabilities will be ranked higher. However, the methods that are closely related to new product planning and development, e.g. the new product portfolio and the technology roadmapping method, were recognized as less important methods. The analytic result implies that the incorporation of the product development success aspect is essential to define the curricula for enhancing the imagination capability of engineering students.

Limitations and Future Work

In this research, the experts were invited for deriving the aspects and criteria. Albeit some existing researches have provided valuable insights for course selection for developing creativity, to the best of our knowledge, this research is the first attempt to derive courses for enhancing imagination capabilities via an MCDM based systematic approach, which considers the influence relationships between criteria. The experts who are responsible for engineering education can provide valuable insights. However, the total number of available Taiwanese experts is fewer than 30. The statistical analysis based approaches, including exploratory and confirmatory factor analysis, are not suitable, as they require more than 30 experts to fulfill the minimum sample number requirements. Therefore, the expert system based approach is more feasible and reasonable for this specific problem.

Meanwhile, the experts are mainly from the industrial design and engineering/technology management related fields with practical product design and development experience. Therefore, the result may be controversial. From this aspect, future research may include studies based on the opinions from faculties of other engineering fields, e.g. electrical engineering, computer engineering/science, mechanical engineering, etc. The studies may derive different course for stimulating imagination capabilities of students belonging to various academic fields.

Table 12. Comparisons of the Ranking of the Methods

Method	DP	w/o DP
TRIZ	2	2
Product Portfolio Theory	4	11
QFD	1	1
Scenario Analysis	6	5
Morphological Method	8	4
The weighted Objective Method	9	6
Technology Roadmapping	5	9
Bionics	12	12
Brain Storming	11	7
SCAMPER	3	3
Objective Tree	13	13
Conjoint Analysis	7	10
Value Engineering	10	8

Remark: "DP" means the ranking of alternatives with the consideration of the design performance aspect; w/o DP means the ranking without considering the design performance aspect.

The unavailability of female experts was another limitation. According to a recent survey by Australian Council of Learned Academies, the number of Taiwanese female academic staff was significantly less than the male one; only around 20 percent of STEM faculties were female (Marginson et al., 2013). This phenomenon is especially significant in most engineering domain. In most engineering programs, the percentage of female faculty can be much lower than 20 percent. Therefore, inviting sufficient experts for opinion provisions was not easy. In the future, surveys on female experts' opinions regarding to the criteria and curriculums influencing engineering imagination capabilities can be a very interesting topic. Since countries generally are grappling with the issue of under-representation of women and girls in STEM (Marginson et al., 2013), and pursue a variety of gender equity policies and strategies to address the engineering imagination related issues will be another important topic.

Experiments on teaching the same methods to engineering students from various academic fields may also bring different results. Other possible research might include the study of the factors influencing engineering imagination capabilities based on empirical studies of larger economies by using the exploratory or confirmatory factor analyses. The results derived based on experts' opinions by MCDM methods and the results derived based on the statistical analyses (e.g., the covariance based structure equation model or the partial least squares method) could further be compared and studied. Other possible studies include the application of the analytical framework in other economies or industries.

Finally, how the methods can enhance specific imagination capabilities of engineering students can be experimented. As discussed in Section "Utilizations of the Finding to Practical Implications", specific imagination capabilities can be enhanced based on the strategies being summarized in **Table 9** as well as the methods highly correlated to the capabilities (refer to **Table 8**). The feasibility of such methods in enhancing imagination capabilities should further be verified by teaching experiment.

CONCLUSIONS

Imagination is a basic human instinct. With plenty of imagination as a source of creativity, both innovation and creativity are needed to produce rich and continuous innovations that contribute to the country's economic boom. Without imagination, humanity cannot sustain the current technology and civilization. In engineering design and technology industries, technology commercialization, technology development, new products (or improved products), manufacturing and marketing processes or equipment related to (technology commercialization) activity, refer to the management and idea generation have strong relationships with imagination. Therefore, the imagination enhancement will be pretty important. Albeit important, few works have explored an appropriate curriculum for developing students' imagination for technology commercialization. In this work, an MCDM-based analytic framework was developed. Courses including the QFD, TRIZ, and SCAMPER were ranked as the most important courses. In the future, the curriculum can be applied to enhance engineering students' imagination capabilities in technology commercialization.

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APPENDICES

Appendix A

DEMATEL

The following are explanations of the DEMATEL calculation steps.

Step 1: Build an initial direct-relation matrix

Experts are asked to indicate the direct influence degree between factor i and factor j, as indicated by a_{ij}, using a pair-wise comparison scale designated with five levels. The initial direct-relation matrix $\boldsymbol{A}$ is obtained by deriving the influence relationships between criteria through Equation (A1).

$$\boldsymbol{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{A1}$$

a_{ij} is denoted as the degree to which the i^{th} objective affects the j^{th} objective.

Step 2: Normalize the direct-relation matrix

The normalized direct-relation matrix $\boldsymbol{N}$ is obtained through Equations (A2) and (A3).

$$\boldsymbol{N} = y\boldsymbol{A} \tag{A2}$$

$$y = \min\left\{1/\max_i \sum_{j=1}^{n} a_{ij}, 1/\max_j \sum_{i=1}^{n} a_{ij}\right\}, i, j \in \{1, 2, ..., n\}. \tag{A3}$$

Step 3: Build the total relation matrix $\boldsymbol{T}$

The total-relation matrix $\boldsymbol{T}$ is acquired by Equation (A4):

$$\boldsymbol{T} = N + N^2 + ... + N^{\varepsilon} = \boldsymbol{N}\left(\boldsymbol{I} - \boldsymbol{N}\right)^{-1} \tag{A4}$$

where $\varepsilon \to \infty$, $\boldsymbol{I}$ is the identity matrix and $\boldsymbol{N} = [x_{ij}]_{n\times n}$.

Step 4: Compute the influence strength of the factors

Aggregate the values of the rows and columns in matrix to obtain $\boldsymbol{T}$ a value r_i and c_i through the Equations (A5) and (A6) respectively. The r_i represents the level of direct or indirect impact on other factors, and c_i represents the level to which it is affected by other factors:

$$r_i = \left[\sum_{j=1}^{n} t_{ij}\right]_{nx1} = [t_i]_{nx1} \tag{A5}$$

$$c_i = \left[\sum_{j=1}^{n} t_{ij}\right]_{1xn} = [t_i]_{nx1} \tag{A6}$$

Step 5: Produce a causal diagram

A causal diagram can be acquired by mapping a data set $(r_i + c_i, r_i - c_i)$. The value of $r_i + c_i$ indicates the strength of influence. The higher the value of $r_i + c_i$ a factor has, the more related it is to the other factors. Similarly, the value of $r_i - c_i$ indicates the causal relationship between factors. If $r_i - c_i$ is positive, then the factor is a "cause factor," dispatching influence to the others. If $r_i - c_i$ is negative, the factor is an "effect factor," receiving influence from others. The higher the value of $r_i - c_i$ a factor has, the more influence it has on the other factors, and hence this factor is presumed to have a higher priority than the others. In other words, the lower the value of $r_i - c_i$ a factor has, the greater its received influence from the other factors, and consequently, the lower the priority it is assumed to have.

Appendix B

DNP

The steps of the DNP method can be summarized as follows:

Step 1: Calculate the direct-influence matrix by scores. Based on experts' opinions, evaluations are made of the relationships among elements (or variables/ attributes) of mutual influence using a scale ranging from 0 to 4, with scores representing "no influence" (0), "low influence" (1), "medium influence" (2), "high influence" (3), and "very high influence" (4). They are asked to indicate the direct effect they believe a factor will have on factor, as indicated by d_{ij}. The matrix $\boldsymbol{D}$ of direct relations can be obtained.

Step 2: Normalize the direct-influence matrix based on the direct-influence matrix $\boldsymbol{D}$, the normalized direct relation matrix $\boldsymbol{N}$ is acquired by using Equation (1) as

$$\boldsymbol{N} = v\boldsymbol{D}; v = \min\{1/\max_i \sum_{j=1}^{n} d_{ij}, 1/\max_j \sum_{i=1}^{n} d_{ij}\}, i, j \in \{1, 2, ..., n\} \tag{1}$$

Step 3: Attaining the total-influence matrix $\boldsymbol{T}$. Once the normalized direct-influence matrix $\boldsymbol{N}$ is obtained, the total-influence matrix $\boldsymbol{T}$ of NRM can be obtained.

$$\boldsymbol{T} = \boldsymbol{N} + \boldsymbol{N}^2 + ... + \boldsymbol{N}^k = \boldsymbol{N}(\boldsymbol{I} - \boldsymbol{N})^{-1} \tag{2}$$

where $k \to \infty$ and $\boldsymbol{T}$ is a total influence-related matrix; $\boldsymbol{N}$ is a direct influence matrix and $\boldsymbol{N} = [x_{ij}]_{n\times n}$; $\lim_{k\to\infty}(\boldsymbol{N}^2 + \cdots + \boldsymbol{N}^k)$ stands for a indirect influence matrix and $0 \leq \sum_{j=1}^{n} x_{ij} < 1$ or $0 \leq \sum_{i=1}^{n} x_{ij} < 1$, and only one $\sum_{j=1}^{n} x_{ij}$ or $\sum_{i=1}^{n} x_{ij}$ equal to 1 for $\forall i, j$ So $\lim_{k\to\infty} \boldsymbol{N}^k = [0]_{n\times n}$. The (i, j) element of matrix $\boldsymbol{T}$ denotes the direct and indirect influences of factor i on factor j.

Step 4: Analyze the result. In this stage, the row and column sums are separately denoted as $\boldsymbol{r}$ and $\boldsymbol{c}$ within the total-relation matrix $\boldsymbol{T}$ through Equations (3), (4), and (5).

$$\boldsymbol{T} = [t_{ij}], \quad i, j \in \{1, 2, ..., n\} \tag{3}$$

$$\boldsymbol{r} = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \tag{4}$$

$$\boldsymbol{c} = [c_j]_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} \tag{5}$$

where the $\boldsymbol{r}$ and $\boldsymbol{c}$ vectors denote the sums of the rows and columns, respectively.

Suppose r_i denotes the row sum of the i^{th} row of matrix $\boldsymbol{T}$. Then, r_i is the sum of the influences dispatching from factor i to the other factors, both directly and indirectly. Suppose that c_j denotes the column sum of the j^{th} column of matrix. Then, c_j is the sum of the influences that factor i is receiving from the other factors. Furthermore, when $i = j$ (i.e., the sum of the row sum and the column sum) $(r_i + c_j)$ represents the index representing the strength of the influence, both dispatching and receiving), $(r_i + c_j)$ is the degree of the central role that factor i plays in the problem. If $(r_i - c_j)$ is positive, then factor i primarily is dispatching influence upon the strength of other factors; and if $(r_i - c_j)$ is negative, then factor i primarily is receiving influence from other factors (C.-Y. Huang, J. Z. Shyu, & G.-H. Tzeng, 2007; Tamura, Nagata, & Akazawa, 2002). Therefore, a causal graph can be achieved by mapping the dataset of $(r_i + s_i, r_i - s_i)$ providing a valuable approach for decision making (see Phillips-Wren, Jain, Nakamatsu, & Howlett, 2010).

Now we call the total-influence matrix $\boldsymbol{T_C} = [t_{ij}]_{n\times n}$ obtained by criteria and $\boldsymbol{T_D} = [t_{ij}^{D}]_{n\times n}$ obtained by dimensions (clusters) from $\boldsymbol{T_C}$. Then we normalize the ANP weights of dimensions (clusters) by using influence matrix $\boldsymbol{T_D}$.

$$\boldsymbol{T_D} = \begin{bmatrix} t_{11}^{D_{11}} & \cdots & t_{1j}^{D_{1j}} & \cdots & t_{1m}^{D_{1m}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{D_{i1}} & \cdots & t_{ij}^{D_{ij}} & \cdots & t_{im}^{D_{im}} \\ \vdots & \vdots & & \vdots & \vdots \\ t_{m1}^{D_{m1}} & \cdots & t_{mj}^{D_{mj}} & \cdots & t_{mm}^{D_{mm}} \end{bmatrix} \begin{matrix} \longrightarrow d_1 = \sum_{j=1}^{m} t_{1j}^{D_{1j}} \\ \\ \longrightarrow d_i = \sum_{j=1}^{m} t_{ij}^{D_{ij}} \quad , d_i = \sum_{j=1}^{m} t_{ij}^{D_{ij}}, i = 1, ..., m \\ \\ \longrightarrow d_m = \sum_{j=1}^{m} t_{mj}^{D_{mj}} \end{matrix} \tag{6}$$

Step 5: The original supermatrix of eigenvectors is obtained from the total-influence matrix $\boldsymbol{T} = [t_{ij}]$. For example, D values of the clusters in matrix $\boldsymbol{T_D}$ as Equation (8). Where if $t_{ij} < D$, then $t_{ij}^D = 0$ else, $t_{ij}^D = t_{ij}$, and t_{ij} is in the total-influence matrix $\boldsymbol{T}$. The total-influence matrix $\boldsymbol{T_D}$ needs to be normalized by dividing by the following formula. There, we could normalize the total-influence matrix and represent it as $\boldsymbol{T_D}$.

$$\boldsymbol{T_D} = \begin{bmatrix} t_{11}^{D_{11}}/d_1 & \cdots & t_{1j}^{D_{1j}}/d_1 & \cdots & t_{1m}^{D_{1m}}/d_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{D_{i1}}/d_i & \cdots & t_{ij}^{D_{ij}}/d_i & \cdots & t_{im}^{D_{im}}/d_i \\ \vdots & \vdots & & \vdots & \vdots \\ t_{m1}^{D_{m1}}/d_m & \cdots & t_{mj}^{D_{mj}}/d_m & \cdots & t_{mm}^{D_{mm}}/d_m \end{bmatrix} = \begin{bmatrix} \alpha_{11}^{D_{11}} & \cdots & \alpha_{1j}^{D_{1j}} & \cdots & \alpha_{1m}^{D_{1m}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \alpha_{i1}^{D_{i1}} & \cdots & \alpha_{ij}^{D_{ij}} & \cdots & \alpha_{im}^{D_{im}} \\ \vdots & \vdots & & \vdots & \vdots \\ \alpha_{m1}^{D_{m1}} & \cdots & \alpha_{mj}^{D_{mj}} & \cdots & \alpha_{mm}^{D_{mm}} \end{bmatrix} \tag{7}$$

where $\alpha_{ij}^{D_{ij}} = t_{ij}^{D_{ij}} / d_i$. This research adopts the normalized total-influence matrix $\boldsymbol{T_D}$ (here after abbreviated to "the normalized matrix") and the unweighted supermatrix $\boldsymbol{W}$ using Equation (9) shows theses influence level values as the basis of the normalization for determining the weighted supermatrix.

$$\boldsymbol{W}^* = \begin{bmatrix} \alpha_{11}^{D_{11}} \times \boldsymbol{W_{11}} & \alpha_{21}^{D_{21}} \times \boldsymbol{W_{12}} & \cdots & \cdots & \alpha_{m1}^{D_{m1}} \times \boldsymbol{W_{1m}} \\ \alpha_{12}^{D_{12}} \times \boldsymbol{W_{21}} & \alpha_{22}^{D_{22}} \times \boldsymbol{W_{22}} & \cdots & \cdots & \vdots \\ \vdots & \cdots & \alpha_{ji}^{D_{ji}} \times \boldsymbol{W_{ij}} & \cdots & \alpha_{mi}^{D_{mi}} \times \boldsymbol{W_{im}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \alpha_{1m}^{D_{1m}} \times \boldsymbol{W_{m1}} & \alpha_{2m}^{D_{2m}} \times \boldsymbol{W_{m2}} & \cdots & \cdots & \alpha_{mm}^{D_{mm}} \times \boldsymbol{W_{mm}} \end{bmatrix} \tag{8}$$

Step 6: Limit the weighted supermatrix by raising it to a sufficiently large power k, as Equation (9), until the supermatrix has converged and become a long-term stable supermatrix to get the global priority vectors or called ANP weights.

$$\lim_{k\to\infty} (\boldsymbol{W}^*)^k \tag{9}$$

According to the definition by Lu, Lin, and Tzeng (2013), the significant confidence level can be calculated by

$$\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{\left|t_{ij}^{p} - t_{ij}^{p-1}\right|}{t_{ij}^{p}} \times 100\% \tag{10}$$

where n denotes the number of criteria. p denotes to the number of experts. t_{ij}^p is the average influence of criterion i on criterion j.

Appendix C

GRA

Since Deng proposed grey theory in 1982 (Julong, 1989), related models have been developed and applied to MCDM problems. Similar to the fuzzy set theory, the grey theory is a feasible mathematical means used to deal with systems analysis characterized by poor information. Fields covered by the grey theory include systems analysis, data processing, modeling, prediction, decision-making and control. In this section, some relevant definitions and the calculation process for the grey relation model will be reviewed. This research modified the original definitions and produced the new definitions as indicated below.

The GRA is used to determine the relationship between two sequences of stochastic data in a grey system. The procedure bears some similarity to pattern recognition technology. One sequence of data is called the "reference pattern" or "reference sequence," and the correlation of the other sequence to the reference sequence is identified (Deng, 1986; Tzeng & Tasur, 1994).

Definition 1: The relationship scale may also be designated into eleven levels, where the scores of 0, 1, 2, …, 10 represent 'no relationship' to 'very high relationship', respectively, between the specified criterion and the alternative, respectively.

Definition 2: The initial relationship matrix G is a $m{\times}n$ matrix, where there are m alternatives and n criteria, obtained by surveying the relationships where g_{ki} is denoted as the relationship between the k^{th} criterion and the i^{th} alternative.

$$\boldsymbol{G}=\begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ g_{21} & g_{22} & \cdots & g_{2n} \\ \vdots & \vdots & g_{ki} & \vdots \\ g_{m1} & g_{m2} & \cdots & g_{mn} \end{bmatrix} \tag{C1}$$

$$\boldsymbol{G_i}=[g_{ki}],\ \ k\in\{1,2,\ldots,m\}$$

Definition 3: The normalized relationship matrix $\boldsymbol{X}$ can be obtained through the Equations (C2) and (C3).

$$p_i=1\Big/\max_{1\le k\le m} g_{ki} \tag{C2}$$

$$\boldsymbol{X}=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & x_{ki} & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{C3}$$

$$\boldsymbol{X_i}=[x_{ki}],\ \ k\in\{1,2,\ldots,m\}$$

$$\boldsymbol{X_i}=p_i\boldsymbol{G_i}$$

Definition 4: Let $\boldsymbol{X}_0$ be the reference pattern with n entries (i.e. dependent variable): $\boldsymbol{X_0}=(x_0(1),x_0(2),\ldots,x_0(n))$ and $\boldsymbol{X}_i$, the matrix containing the normalized mapping information of each alternative to the criteria, be one of the m patterns with n entries to be compared with the $\boldsymbol{X_0}$ where $\boldsymbol{X}_i$ is written as: $\boldsymbol{X}_i=\left(x_i(1),x_i(2),\ldots,x_i(n)\right), 1\le i\le m$. The sequence $\boldsymbol{X}_i$ generally expresses the influencing factor of $\boldsymbol{X}_0$.

Definition 5: Let $\boldsymbol{X}$ be a normalized factor set of grey relation, $\boldsymbol{X_0}\in\boldsymbol{X}$ the referential sequence, and $\boldsymbol{X}_i\in\boldsymbol{X}$ the comparative sequence; with $\boldsymbol{X}_0(k)$ and $\boldsymbol{X}_i(k)$ representing respectively the numerals at point k for $\boldsymbol{X}_0$ and $\boldsymbol{X}_i$. If $\gamma(\boldsymbol{X}_0(k),x_i(k))$ and $\gamma(\boldsymbol{X}_0,x_i)$ are real numbers, and satisfy the following four grey axioms, then call $\gamma(\boldsymbol{X}_0(k),x_i(k))$ the grey relation coefficient and the grade of grey relation $\gamma(x_0,x_i)$ is the average value of $\gamma(x_0(k),x_i(k))$.

1. Norm Interval

$$0<\gamma(x_0(k),x_i(k))\le 1,\ \forall k;\ \gamma(\boldsymbol{X}_0,\boldsymbol{X}_i)=1\ iff\ \boldsymbol{X}_0=\boldsymbol{X}_i;$$
$$\gamma(\boldsymbol{X}_0,\boldsymbol{X}_i)=0\ \ iff\ \ \boldsymbol{X_0},\boldsymbol{X}_i\in\phi;$$

where ϕ is an empty set.

2. Duality Symmetric

$$\boldsymbol{Y},\boldsymbol{Z} \in \boldsymbol{X} \;\Rightarrow\; \gamma(\boldsymbol{Y},\boldsymbol{Z}) = \gamma(\boldsymbol{Z},\boldsymbol{Y}) \; iff \;\; \boldsymbol{X} = \{\boldsymbol{Y},\boldsymbol{Z}\}.$$

3. Wholeness

$$\gamma(\boldsymbol{X}_i,\boldsymbol{X}_j) \overset{often}{\neq} \gamma(\boldsymbol{X}_j,\boldsymbol{X}_i) \quad iff \quad \boldsymbol{X} = \{\boldsymbol{X}_i \big| i = 0,1,\ldots,n\}, \quad n > 2.$$

4. Approachability

$\gamma(x_0(k), x_i(k))$ decreases when $|(x_0(k) - x_i(k))|$ is increasing.

Deng also proposed a mathematical equation for the grey relation coefficient as follows:

$$\gamma(x_0(k), x_i(k)) = \frac{\min\limits_{\forall j, j\in i} \min\limits_{\forall k} \left|(x_0(k) - x_j(k))\right| + \zeta \max\limits_{\forall j, j\in i} \max\limits_{\forall k} \left|(x_0(k) - x_j(k))\right|}{\left|(x_0(k) - x_i(k))\right| + \zeta \max\limits_{\forall j, j\in i} \max\limits_{\forall k} \left|(x_0(k) - x_j(k))\right|} \tag{C4}$$

where ζ is the distinguished coefficient ($\zeta \in [0,1]$). Generally, we pick $\zeta = 0.5$.

Definition 6: If $\gamma(x_0, x_i)$ satisfies the four grey relation axioms, then γ is called the Grey Relational Map.

Definition 7: If Γ is the entirety of the Grey Relational Map, $\gamma \in \Gamma$ satisfies the four axioms of grey relation, and $\boldsymbol{X}$ is the factor set of grey relation, then $(\boldsymbol{X}, \Gamma)$ will be called as the grey relational space, while γ is the specific map for **Γ**.

Definition 8: Let $(\boldsymbol{X}, \Gamma)$ be the grey relational space, and if $\gamma(\boldsymbol{X}_0, \boldsymbol{X}_j), \gamma(\boldsymbol{X}_0, \boldsymbol{X}_p), .., \gamma(\boldsymbol{X}_0, \boldsymbol{X}_q)$ satisfy $\gamma(\boldsymbol{X}_0, \boldsymbol{X}_j) > \gamma(\boldsymbol{X}_0, \boldsymbol{X}_p) > \cdots > \gamma(\boldsymbol{X}_0, \boldsymbol{X}_q)$ then we have the grey relational order as $\boldsymbol{X}_j \succ \boldsymbol{X}_p \succ \cdots \succ \boldsymbol{X}_q$.

When the grey relational coefficient is conducted, we can then derive the grade of grey relation $\gamma(\boldsymbol{x}_0, \boldsymbol{x}_i)$ between the reference and alternative imagination stimulation courses.

$$\gamma(\boldsymbol{x}_0, \boldsymbol{x}_i) = \sum_{k=1}^{n} \omega_k \times \gamma(x_0(k), x_i(k)). \tag{C5}$$

where k is the number of criteria, ω_k expresses the weight of the k^{th} criteria, and $\gamma(\boldsymbol{x}_0, \boldsymbol{x}_i)$ represents the grade of grey relation in x_i (the k^{th} imagination stimulation course) correspondence to x_0. In this study, we rank the imagination stimulation courses based on the grey grades.