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An empirical study on the incorporation of APP and progressive reasoning teaching materials for improving technical creativity amongst students in the subject of automatic control

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ABSTRACT

This study reformed teaching materials for automatic control, a mandatory course for engineering students, and designed a set of digital teaching materials based upon progressive reasoning with hand-mind combinations. The teaching materials were mainly delivered via a hands-on APP. The authors conducted an empirical study as well as pre-tests and post-tests for a total of 118 sophomore students majoring in engineering at two Universities. Outcomes found that the progressive reasoning teaching materials designed for this course were helpful in improving student creativity and scientific reasoning. Significant improvements were also achieved in product design, technical methods, and technological ideas aspects of technological creativity and every scientific reasoning skill, with the exception of proportional reasoning. Results also identified strong correlation between technical creativity and scientific reasoning. This relationship may be further investigated in follow-up studies. This study also proposed recommendations for coordinating designs of digital teaching materials in other engineering courses with the development of student thinking.

1. Introduction

Creativity has always been a topic investigated by researchers in psychology, pedagogy, and the social sciences. The concept of creativity has continued to baffle the academic world and represented one of the most difficult concepts to define (Feldhusen, 1995). Human creativity was responsible for driving human progress, bringing wealth and improving the quality of life. In his book on creative talents, Guilford mentioned that having a talent and knowing how to use that talent would be very different concepts. Knowing when to apply that talent or the ability use that talent effectively would be a separate thing altogether. The same rules would apply to creativity. Creativity is a form of creative talent generated during creative activities (Nickerson, 1999). Technical creativity can be regarded as an extrinsic or potential creative talent demonstrated when performing activities related to technical creativity, or when preparing to undertake technical creation or scientific research. The various features and strategies for developing research and technical creativity aim to fully unleash the maximum potential of individuals involved in technical creation or scientific research and to identify people that may have immense potential for technical creativity (Runco, 1996).

1.1. Methods for studying creativity

Creativity has a very special meaning for human survival and development. Many researchers have therefore investigated the nature of human creativity. The British psychologist S.F. Galton (1869) was the first to successfully employ statistics and empirical reasoning to define creativity as an observable, measurable human characteristic. Since then, human creativity has been systematically studied for over a century. During this period, investigations on human creativity were conducted via 3 major methods: 1. Observation, tracking surveys, and experiments to dissect the inner workings of creative mindsets, its psychological processes, influencing factors, principles of discovery and creation, as well as processes and methods to encourage human creativity.

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The American psychologist L.M. Terman (1922) and his assistants spent more than 50 years conducting a tracking study of talent development of 1500 children gifted with extraordinary intelligence. The outcomes of this research provided vast amounts of first-hand information with great scientific value on the relationship between creativity and intelligence. 2. Biographical studies or interviews with people known for their high levels of creativity (scientists, inventors, politicians, and artists) in order to uncover the thinking processes, creative methods, and personality traits of creative people. These included a series of studies on well-known writers, architects, mathematicians, and outstanding scientists conducted by the American psychologist Anne Roe in 1952 as well as Mackinnon, Barron, and their assistants from the Institute of Personality and Social Research (IPSR) of UC Berkeley. In the 1990s, world renowned psychologist and expert on creativity, Mihaly Csikszentmihalyi (1996) from the University of Chicago, performed a series of interviews with creative elites from various aspects of society. Creativity was described along 3 dimensions of personal upbringing, professional work, and peer assessment. The outcomes of his studies were later used to propose the mechanism of creative flow. 3. Creativity testing was used. Statistical analysis of creative testing outcomes were used to make direct, quantitative assessments and predictions to creativity or creative potential amongst people. Tests of Creative Thinking developed by the American psychologist Torrance (1980) as well as the *Skill Inclination Research Program* of the University of Southern California (USC) directed by the late American psychologist J.P. Guilford (1950) would be examples of these testing processes.

1.2. Concepts and researches on technical creativity

After analyzing the outcomes of over 100 studies on creativity, the American psychologist Hutchison summarized the main characteristics of creativity as: (1) Originality, something that never existed before that serves as the main defining feature of creativity; (2) novelty, which would be a new and extraordinary creative design. Novelty may seem similar to originality, but originality refers to something that never existed before, while novelty refers to something new and different compared to the other similar products; (3) fluency, which would be the number of concepts reflected per unit time; (4) flexibility, which would be a sensitivity to the difficulty faced by the problem, the ease of identifying the need for improvement, and the ability to come up with a solution when encountering items or issues in an objective environment; (5) elaboration, which would be the ability to use precise and thorough methods for an ongoing work and the capacity of extensively reviewing and considering every part of the problem as well as the overall picture.

Guilford, another American psychologist, believed that the main characteristics of creativity were: (1) sensitivity, which would be the ease of accepting new phenomenon or discovery of new problems; (2) fluency, which would be a measure of mental agility and reaction speed, and the ability by which the person successfully proposes multiple reactions or answers toward specific questions or scenarios; (3) flexibility, which would be responsiveness and adaptability to adjust the direction of efforts carried out to realize the proposed ideas; (4) originality, which would be the ability to generate new and outstanding ideas, manifested by the creation of new, rare, and novel concepts and results; (5) redefinition, which would be the ease in discovering the multiple uses of special incidents and items; (6) penetration, which would be the ability to identify and subsequently make changes to the meaning, characteristics, or diversity of objects by studying observable features.

Having summarized the above, it was obvious that both psychologists included originality, fluency, and flexibility as the major features of creativity, proving that these 3 dimensions should be the core features. Additionally, both psychologists also expressed their own inclinations on the definition of creativity. One emphasized precision, while the other focused upon sensitivity. In the early 1980s, the Harvard psychologist H. Gardner (1983) proposed the novel concept of multiple intelligences as he believed that people have many different types of intelligences. Gardner identified 7 forms of intelligences, namely linguistic, logical-mathematical, visual-spatial, musical, bodily-kinesthetic, interpersonal, and intrapersonal abilities. Despite being focused on human intelligence, Gardner's theory also established strong correlations between intelligence and creativity. This entire theory of multiple intelligence could be used as an inspiration or reference for researchers studying creativity. Since there were many types of intelligences, there should be multiple types of creativity as well. Creativity can be categorized according to its mode of expression in various fields and subjects, such as literature and art, mathematics, and technology (in science technology). Technical creativity would also refer to creativity demonstrated in the fields of scientific technology. The major consensus established by major studies would be that knowledge and skills in a field of expertise would be a major component of creativity. It would be necessary to study creativity in an actual field, especially since technical creativity has invoked the interest of many investigators. Technical creativity would be the quality or ability of intelligence demonstrated during the process through which an individual or organization creates a product in a unique, novel, and valuable (or appropriate) way for a certain purpose by utilizing their body of knowledge within the field of technical expertise. The cognitive process of technical creativity was studied by Ye (2006). Kim, Kim, Lee, and Park (2007) also compared the cognitive processes during technical creativity between students and experts. Ye investigated 3 interactions, the ecology that influence technical creativity, as well as factors based upon personal characteristics. Hong and Sheu (1999), on the other hand, studied the process of developing technical creativity to arrive at a feasible method. Christians (1992) developed a means of evaluating technical creativity from an industrial perspective. In general, studies on technical creativity focused upon cognitive processes, factors, cross-cultural comparisons, and assessments. However, very few investigations have been carried out on the development and actual practice of technical creativity in pedagogy.

1.3. Development of scientific reasoning and teaching materials

Scientific mindset is the core of this ability and the basis of creativity. Studies on the development and advancement of scientific mindset amongst youths would be extremely meaningful to the development of creative talents. Scientific reasoning is an advanced method of thinking developed by the human race and was key in helping us gain a better understanding of the world. The concept of scientific reasoning was first mentioned by Piaget in his knowledge development theory (Wang, Guo, & Jou, 2015). Since the 1960s, scientific reasoning has become a key area of psychological research in other countries. These studies often categorized scientific reasoning by the subject of reasoning into 5 major categories of control variables, consolidative reasoning, proportional reasoning, relational reasoning, and probabilistic reasoning. Cognitive development standards among children were then employed to divide various types of reasoning into stages such as actual computation, transition phase, and formative calculations.

Piaget first proposed the concept of scientific reasoning in his theory of cognitive development, believing that scientific reasoning is the reasoning model adopted by children or adults whose level of cognitive development has reached the operational stage. Kwen

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