Work in Progress: Influence of Cognitive Concept Connection, Personal Motivations, and Personal Characteristics when Assessing Creativity

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Abstract

Industry now requires interdisciplinary and creative thinking skills because of a paradigm shift in target markets. Therefore, modern engineering education should focus on developing students' innovative thinking for solving engineering problems and design courses to foster students' creativity, critical thinking, and ability to transfer their skills. This study employed the widely used Moodle learning platform for courses on computer science and engineering. Appropriate guidance from the platform regarding the different objectives of five project stages enabled group members to communicate, exchange, and interact, and the students gradually developed their thinking from divergent to convergent. Through deep analysis of the students' learning portfolios, the effects of cognitive concepts, personal motivations, and personal characteristics on creativity were investigated. Moreover, this study further explored three issues regarding the differences between highly and lowly creative students so that teachers could employ appropriate teaching resources or assistance. The findings of this study can help teachers provide timely guidance and responses to students. Fostering students' creative thinking and unleashing their imagination thus develops their capacity for innovation, which is now essential in engineering education.

Introduction

Competitive market structures are changing, and industry is gradually demanding an increasingly large number of cross-disciplinary and innovative employees. Therefore, engineering education should, in addition to teaching traditional skills, also focus on training students in the ability to solve engineering problems innovatively. Creative thinking and an integrated curriculum can be used to develop students' creative thinking, critical reflection, and adaptation skills.

Creativity education curricula have traditionally differed because there are different opinions and explanations among educators about the definition of creativity. Some consider creativity as the ability to invent, whereas others classify creativity as divergent thinking or even imagination [1]. In short, creativity is the ability to create and to innovate and is a characteristic and an ability of creative people [2, 3]. When

evaluating creativity within education, projects completed by students are usually used as the evaluation criterion, and the process, environment, and characteristics of creativity themselves are rarely explored or analyzed. Although some studies on the subject have been performed, the majority have only defined or probed the development of creative thinking from a single dimension.

All current learning management platforms collect digital learning portfolios. The biggest advantage of digital process records is the ability they offer to integrate different digital information and record and present data in varied ways. The environment and conditions necessary to stimulate creativity are clearly indicated by the dynamic and authentic records and analyses of learning portfolios. Detailed portfolio analyses and discussions regarding structured contents can enable the discovery of associations and factors that encourage creativity. Therefore, if the learning platform can be integrated into the creativity education curriculum, rich data regarding the development of creativity can be explored through the diversified learning portfolio records. Using structured analyses, the behavior and characteristics of the students' creativity development can be effectively identified, facilitating research into creativity process and behaviors.

Motivation has always been considered one of the most crucial personality traits related to creativity [4]. Creative people can always devote themselves single-mindedly to creative work. High-level motivation can thus easily lead to creative behavior [5, 6], and other personality traits have also been demonstrated to affect the development of creativity. Smith, Michael, and Hocevar discovered that in a stressful environment, individuals inhibit their mathematical creativity in addition to their divergent idea generation [7]. Dollinger and Clancy reported that each of the big five personality traits (openness to experience, neuroticism, extraversion, agreeableness, and introversion) were involved with the presentation of creativity [8].

Considering these factors, this study introduced the Moodle learning platform into computer science and engineering courses. The platform progressively helped team members to communicate, exchange, and interact and offered appropriate guidance for the goals of the five stages of the project. Team members were guided toward divergent thinking as a means of resolving difficulties during group discussions. The students’ learning portfolios were recorded in the back-end database. This study collected, analyzed, and explored these learning portfolios to clarify and understand the effect of cognition concept connections, personal motivation (work preference), and personality traits (achievements, goals and problem-solving styles) on creativity development factors and conditions. Then, a more detailed analysis was conducted on

these three dimensions to identify the major differences between highly and lowly creative people and hence provide teachers with appropriate teaching resources and counseling. The overall analysis results can be used to follow-up the courses' teaching efforts and provide real-time feedback in an effort to enhance students' idea generation skills, strengthen their connection between creativity and imagination, and consequently increase their innovation skills.

Learning System

This study is based on the results of previous related studies. The Moodle learning platform was adopted, using which users interacted with the platform through web pages. A modular architecture was employed, and modules were divided into core modules and plug-in modules. When adding new features, Moodle plug-in modules were used to connect the new module to the original core module. Moodle has different types of plug-in modules, and this study used the Activity Module to meet the study's teaching design, which employed project-based learning (PBL) and the SCAMPER teaching strategy. The web servers used Apache and PHP syntax, whereas the database was a MySQL relational database. A remote video conferencing suite (JoinNet) was installed on the Moodle learning platform to support synchronous and interactive discussions among students. Thus, the students could access a wide range of learning tools for subject exploration and peer interaction, all on a single interface. In addition, all interactions and conversations between students were recorded on a back-end database for follow-up analysis and research.

The system interface and functions were planned and designed based on the stages of the corresponding course's teaching strategy. The system interface is presented in Figure 1. It encompasses all the basic functions provided by most learning platforms, such as calendar reminders, a discussion forum (asynchronous), video conferencing (synchronous), homework hand-in capability, and feedback and evaluation provision. A particular feature of this learning platform was that it was divided into five stages in accordance with the introduced PBL and SCAMPER teaching strategies: preparation, implementation, presentation, evaluation, and revision. At each stage, students could use the activity modules provided by the system to complete tasks and discuss relevant topics. The diverse learning tools and real-time activities on the platform could effectively assist the students achieve high grades in the project tasks. Through participation and investment in the activities, discussions within and between groups was encouraged, creative thinking was developed, and diverse idea generation was fueled, thereby providing the students with advanced cognitive learning skills.

Figure 1. Interface of Moodle learning system

Research Design

Participant

The participants in this study were 52 juniors taking courses (1) and (2) on computer science and engineering from the engineering college of a national university in Taiwan. Thirteen groups of four students each were created. Each student progressively completed PBL and SCAMPER activities using instructions and guidance supplied on the Moodle learning platform. Various functions and tools of the platform facilitated exchanges and discussions between the groups. Interactions between the groups stimulated students' different ways of thinking and characteristics and exercised team members' imagination, reasoning, and problem-solving skills. To ensure that each group of students executed the projects to the best of their ability and made an attempt to learn from the activities, their results from this experiment were included as part of their academic grade in that semester.

Experimental procedure

Courses (1) and (2) on computer science and engineering projects were delivered in

two semesters, spanning over 18 weeks, and two lessons were given each week. The experimental procedure is illustrated in Figure 2. In the first week of the first semester, teachers explained to students the goals of the course and the process and content of each stage. Students were required to complete the Torrance Tests of Creativity Thinking (TTCT), through which their creative ability was evaluated. In the second week of the first semester, students were heterogeneously grouped based on their TTCT test results. Students were also asked to familiarize themselves with the functions of the platform, which would facilitate smooth progress during the follow-up learning activities. The third to the ninth week of the first semester was used for the preparation stage of the PBL. During this stage, students used an array of the platform's auxiliary functions to discuss project direction and scope, set the project's topic and direction, and plan their progress and goals. They used the seven dimensions of the SCAMPER strategy—substitute, combine, adapt, modify, put to other use, eliminate, and rearrange—to improve and change their direction of thought, hammer out new ideas and methods, and further innovate and improve based on existing knowledge areas. The implementation stage lasted from the tenth week of the first semester to the eighth week of the second semester. During this stage, students from different groups used the various functions of the platform to discuss and interact with each other regarding the construction and implementation of their projects. They could thus combine their knowledge and discuss conceptual principles to help with solving problems, in addition to training themselves to consider multiple perspectives and honing their problem-solving skills. This developed their critical thinking ability through teamwork, discussions, and the division of labor. The publication stage lasted from the ninth week to the thirteenth week of the second semester. Before the official project publication, team members interacted using the discussion function of the platform, practiced their presentations of the project outcome using the synchronous video conferencing, and submitted document data using the data upload function. The groups were encouraged to adopt a vast variety of methods to present the project achievements. After each group had finished their report, the other groups immediately gave feedback and recommendations. It was hoped that the students would observe and learn through their sharing of project achievements. The 14th week of the second semester was the evaluation stage. Teachers offered an evaluation and recommendations based on the learning results and the students' learning process and uploaded the recommendations and evaluation results to the learning platform. Aside from understanding and discussing their project evaluation results and recommendations, the students were required to complete a questionnaire about problem-solving styles on the learning platform. The 16th and 17th weeks of the second semester were the revision stage. Based on the feedback

received from teachers and peers, the students reflected, coordinated, and communicated with each other, after which they revised the project report and assessed what they had learnt. During the 18th week of the second semester, the students were asked upload the revised project report to the learning platform and were requested to complete the TTCT, job motivation scale, and achievement and goal questionnaire.

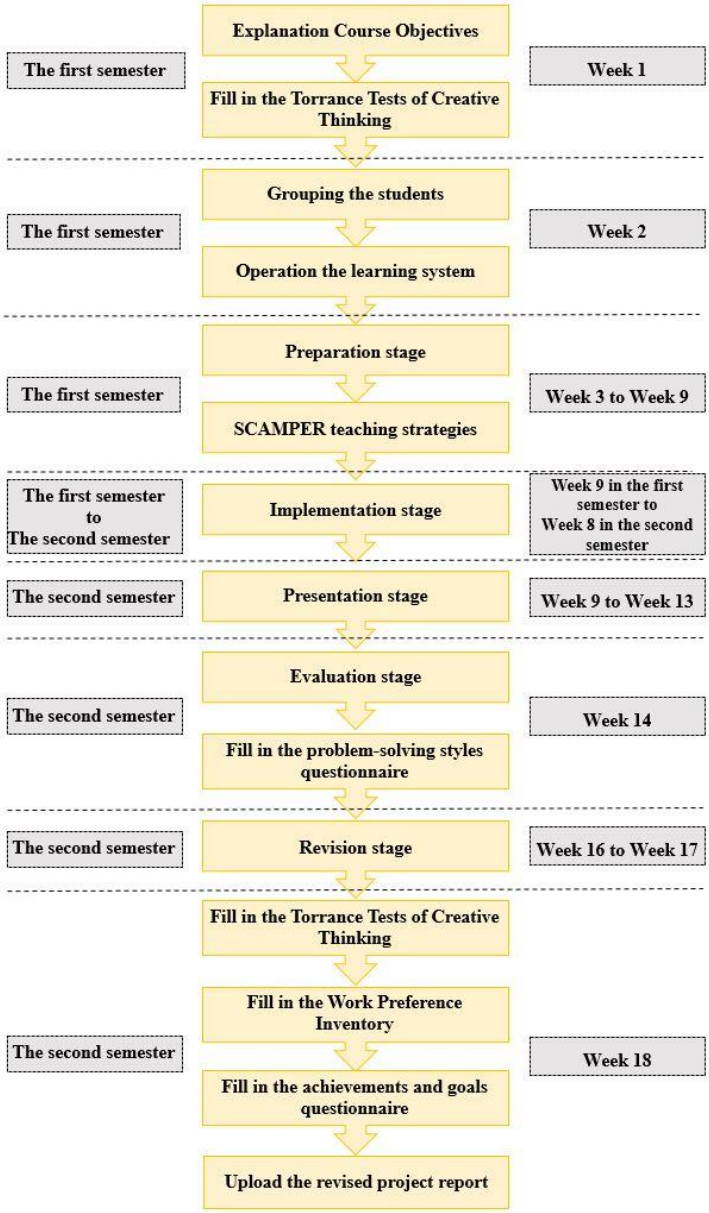

Figure 2. The experimental procedure

Assessment tools

(1). Torrance tests of creative thinking

The TTCT, compiled by Torrance at the University of Minnesota in 1966 [1], is currently the most widely used test of creativity for people of all ages. It consists of a speech-creation thinking test, a picture-creation thinking test, and a creative thinking test involving sounds and words. These tests are formulated as games so the test process is easy and pleasant. The pretest and posttest results indicated the students' personality traits and performance after they had participated in PBL and SCAMPER teaching strategy activities.

(2). Discussion contents

The associative theory proposed by Mednick emphasized the importance of ideas and held that the essence of creative thinking was the connection of seemingly unrelated concepts [9]. Consequently, this study analyzed cognitive concept connections using the students' discussion forms (asynchronous) and video conferencing records (synchronous). First, the CKIP Chinese word segmentation system was used to convert the original text into numbers [10], and then a support vector machine (SVM) was employed to classify the discussions. Next, k-means clustering analysis was used to examine the cognitive concept connections and frequently used keywords that arose during discussions between highly creative and lowly creative students.

(3). Personal motivations

The key creativity motivators were enthusiasm for the work itself and the pleasure brought by the work. Thus, high-level motivations prompted creation behaviors [11]. This study quoted and revised the Work Preference Inventory (WPI) proposed by Amabile et al. to evaluate students' internal and external motivations for learning contents [12]. The WPI judged the participants' psychological motivations for the target job content using components of internal and external motivations.

(4). Personality traits

All personality traits are associated with creativity [13]. To probe the relationship between personality traits and creativity, this study adopted two questionnaires. The first concerned definitions of achievements and goals and was revised based on the contents of Elliot and McGregor [14]. The second concerned problem-solving styles. These questionnaires were then analyzed to understand whether the students preferred intuitive or systematic solution types when facing and solving problems.

Research Results

Analysis of the TTCT

The TTCT comprises three activities, each of which lasts for approximately 40 minutes, and the test result scores can be divided into five dimensions. The analysis results of the pretest and posttest are presented in Table 1. The students demonstrated significant differences in fluency, abstractness of the title, elaboration, and resistance to premature closure comparing pretest with posttest, after the PBL and SCAMPER teaching strategy activities. The results revealed that the progressive guidance and diverse interactions and exchanges on the learning platform encouraged the students' thinking to be efficient and their ideas more diverse. During cognition, the students acquired the ability to discern the nature of core problems, analyze, and evaluate. Additionally, they could adopt an attitude that was open-minded and promoted rigorous thought, understanding various messages and the perspectives of different parties.

Table 1. The grades of three evaluation methods.

Dimensions	**M***(Pre-test)*	**M***(Post-test)*	**SD**	***t***
Fluency	94.51	112.32	18.87	4.59*
Original	101.33	109.29	25.54	1.72
Abstractness of the title	70.61	105.29	24.15	5.995*
Elaboration	64.96	82.11	14.01	4.984*
Resistance to premature closure	91.19	104.82	25.58	5.56*

*$P < .05$

Analysis of cognitive concept connections

Cognitive concept connections were identified using the discussion forum (asynchronous) and video conference records (synchronous). First, all the interaction and discussion content was converted into text files. Text is nonstructural data, so the original text was then converted into numbers. The content was next processed through two steps: word segmentation and word frequency. Regarding word segmentation, the CKIP Chinese word segmentation system developed by Academia Sinica was employed. Regarding word frequency, term frequency–inverse document frequency (TF-IDF), which can evaluate the significance of a word in a file set or corpus, was used to extract the text features. An SVM was used to classify the discussion content, and a k-means clustering method was adopted to analyze the wording features and keywords discussed on the platform by highly and lowly creative students.

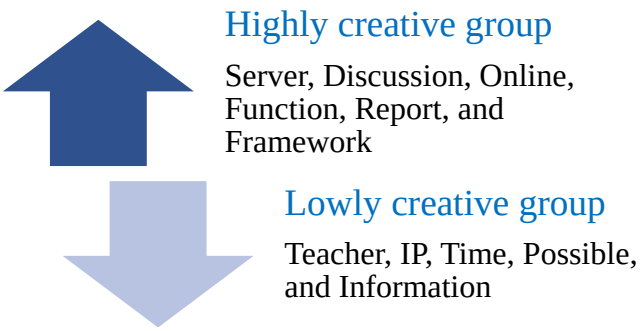

Figure 3. The discussion contents of two major groups

The discussion content was classified into two major groups according to the highly and lowly creative groups, as illustrated in Figure 3. The clustering results revealed that the most crucial keywords used during the discussions of the highly creative group were server, discussion, online, function, report, and framework. Therefore, the discussion content of the highly creative students was specific and concerned results, reports, and system building. By contrast, the most crucial keywords used during the discussions of the lowly creative group were teacher, IP, time, possible, and information. These keywords revealed that their discussions were passive and their interactions were superficial and abstract. Instructors can use these analysis results to effectively understand students' discussions and offer timely assistance and guidance.

Analysis of personal motivations

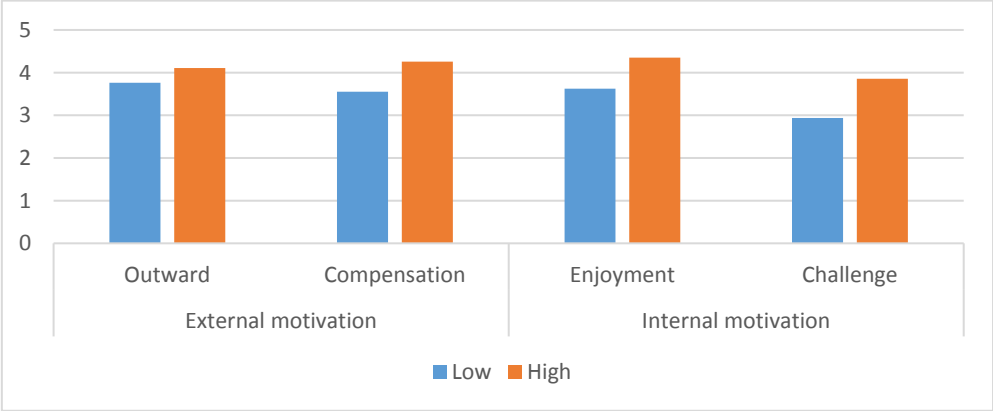

Figure 4. The statistical analysis results of the WPI

Statistical analysis of the 30 WPI questionnaire items is detailed in Figure 4. The internal (enjoyment and challenge) and external (outward and compensation) motivations of the highly creative students were discovered to be higher than those of the lowly creative students. The difference in work challenge motivation was particularly significant. Highly creative students are thus more willing to accept

complex and difficult work challenges.

Analysis of personality traits

The questionnaire about achievements and goals was revised based on the study of Elliot and McGregor and consisted of 13 items [14]. The definitions of achievements and goals were divided into four categories: performance-approach, performance-avoidance, mastery-approach, and mastery-avoidance. According to the results presented in Figure 5, the highly creative students were more likely to take risks and make an attempt, to pursue constant self-growth, and to demonstrate their skills by outperforming others. By contrast, the lowly creative students avoided acquiring deeper knowledge so as to avoid making mistakes and were less ready to demonstrate their skills to the public, which may have degraded their public image and led to accusations of incompetency.

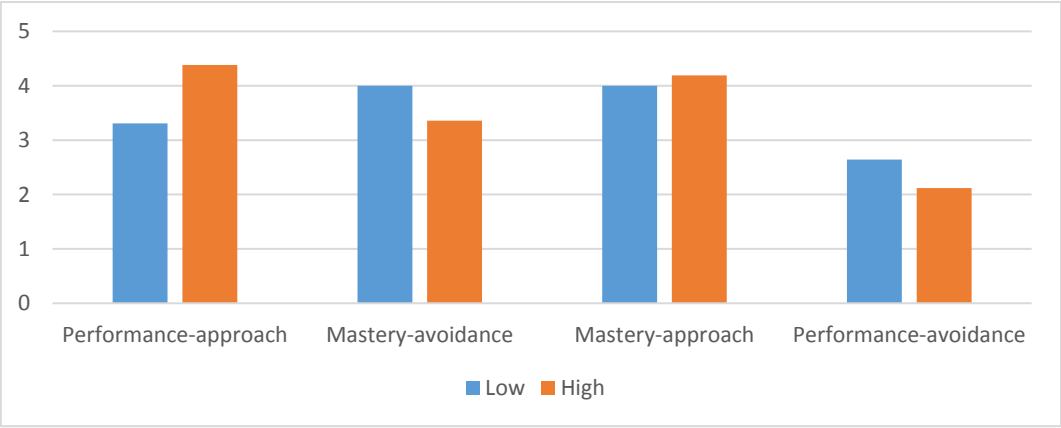

Figure 5. The statistical analysis results of the achievements and goals

The questionnaire about problem-solving styles, including 13 items, primarily explored whether the students preferred intuitive or systematic solution types when facing and solving problems. According to the results presented in Figure 6, the highly creative students preferred to solve problems in an intuitive way, tended to consider information from different perspectives when processing it, were willing to spend extra time investigating the relationships between different areas, and also actively sought new problem-solving methods. Regarding systematic solution types, there was little difference between the highly and lowly creative students. From the records of observations and discussions, it was concluded that the students were affected by the teaching methods used in their country and culture, preferring the use of familiar techniques, methods, and procedures. Additionally, they were also discovered to comply rigorously with established routines of project completion.

Therefore, there were no differences concerning systematic problem-solving styles between the highly and lowly creative students.

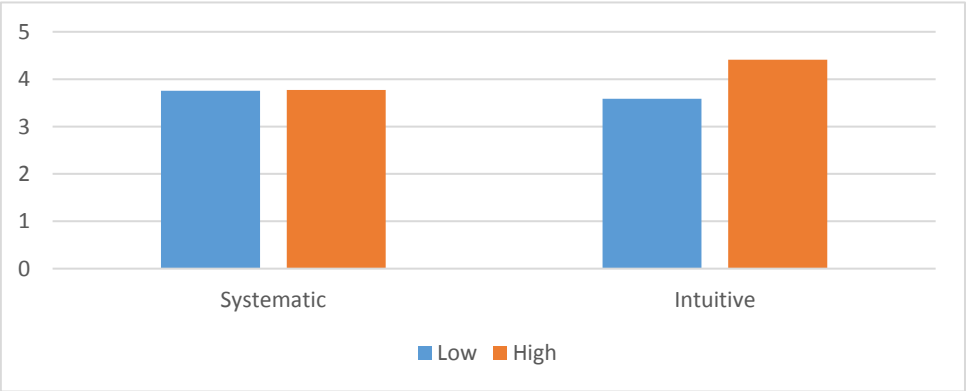

Figure 6. The statistical analysis results of the problem-solving styles

Conclusion and Future Studies

With competition fierce in what is a now global market, industry is in urgent need of employees who can independently design, innovate, and develop unique ideas. To meet these needs, most schools place a high value on engineering education curriculum design so that they produce cross-disciplinary and highly creative individuals who are able to solve problems. Therefore, how to provide students with appropriate courses and activities and how to hone students' innovation skills has become a focus of engineering education.

In most courses, completed projects are generally used to evaluate students' creativity, or creativity is only developed from a single perspective. Few studies have analyzed the development process, environment, and characteristics of creativity. If the value of creativity could be investigated through records of students' project completion strategies, this would contribute to the research into creativity and behavior guidance. Therefore, this study used Moodle as a learning platform and introduced PBL and SCAMPER teaching strategies as the base. The platform enabled group members to communicate, exchange, and interact while completing each of the five project stages. The effect of cognitive concept connections, personal motivation, and personality traits on creativity development was investigated using the collected and analyzed data.

According to the results of the TTCT, students had more diverse ideas for projects and could take an attitude that was open-minded and promoted rigorous thought after taking part in PBL and SCAMPER teaching strategy activities. Analysis of the

cognitive concept connections indicated that the discussions of the highly creative students were more specific and less superficial than those of the lowly creative students. Additionally, the statistical results of the WPI questionnaire revealed that the highly creative students were more willing to accept work challenges and had higher internal and external motivations than the lowly creative students. Personality trait questionnaire analysis indicated that highly creative students were more likely to take risks and make an attempt, to pursue constant self-growth, and to actively seek new problems and solutions from different angles. By contrast, lowly creative students were less willing to demonstrate their skills to the public and generally sought solutions for problems using known techniques. The analysis results of the different dimensions suggested that the majority of highly creative students were willing to actively look for, probe into, and analyze information and to share, exchange, and discuss with others through the learning platform. Consequently, their curiosity and thirst for knowledge were greater, driving them to imagine, reason, contemplate, and resolve problems. Such learning behaviors are creative thinking skills, similar to the research conclusion made by Collette and Chiappetta [15].

This study was part of a three-year program that is still underway. In this study, a preliminary analysis and understanding of students' creativity analysis, cognitive concept connections, personal motivations, and personality traits after students participated in PBL and SCAMPER teaching activities on the platform was performed. In the future, in-depth exploration and analysis of the relevance of each dimension will be performed. Moreover, student learning behaviors, cognitive style, cognitive load, and learning anxiety will be evaluated and examined.

Acknowledgements

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