Work in Progress: Constructing a Prediction Model of Creativity and Cognitive Concept Connections Based on Learning Portfolio

Prof. Ting-Ting Wu, Graduate School of Technological and Vocational Education, National Yunlin University of Science and Technology

Ting-Ting Wu is currently an Associate Professor in the Graduate School of Technological and Vocational Education at National Yunlin University of Science and Technology, Taiwan. She received her Ph.D. degree from the Department of Engineering Science at National Cheng Kung University. She received the MS degree in Information and Learning Technology from National University of Tainan. Her research interests include mobile and ubiquitous learning, information technology-applied instructions and intelligent learning systems.

Prof. Yueh-Min (Ray) Huang, Cheng-Kung University

Dr. Yueh-Min Huang received his MS and Ph.D. degrees in Electrical Engineering from the University of Arizona, respectively. He is currently a chair professor of the Department of Engineering Science and associate dean of Engineering College at National Cheng-Kung University, Taiwan. His research interests include e-Learning, embedded systems and artificial intelligence. He has co-edited 3 books published by Springer Verlag and has published over 250 refereed journal papers. His works have received over 5000 Google citations in recent 5 years. Dr. Huang has received many research awards, including best paper awards, such as GCCCE2013 and national competition prizes, such as the first prize of ARM Code-O-Rama 2012. He is also a winner of the distinguished research award of the National Science Council, Taiwan in 2010 and 2013, respectively. Dr. Huang is in the editorial board of several SSCI- and SCI-indexed journals such as Interactive Learning Environments and Wireless Communications and Mobile Computing. He was the technical program chair of International Conference on Web-based Learning (2013) and the general chair of AECT International Conference on the Frontier in e-Learning Research 2013 (ICFER) and the e-Learning Forum Asia 2014. Dr. Huang became a Fellow of British Computer Society (FBCS) in 2011 and a senior member of the IEEE.

Mr. Pei-Yu Cheng, Dept. of Engineering Science, National Cheng Kung University

Pei-Yu Cheng is a Ph.D. student in the Department of Engineering Science at National Cheng Kung University, Tainan, Taiwan. He received his Master degree from the Department of Information Engineering at Kun Shan University, Taiwan, in 2013. His main research interests include E-Learning, Learning Technology, Mobile learning, E-Books. He is working on his doctoral program under his advisor, Prof. Yueh-Min Huang.

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Abstract

The skills required of new employees by industry are increasingly interdisciplinary and creativity-related because of a paradigm shift in target markets. Engineering education should therefore focus on helping students develop their creativity and critical thinking skills. A student's level of creativity is usually evaluated by examining his or her final projects. However, the language that students use in discussions and interactions can be analyzed to determine their cognitive processes and thus their creativity. This study collected 1 year of records of discussions and interactions on a Moodle learning platform among students in two college courses (Computer Science and Engineering). The discussions and interactions were filmed and recorded in a backend database and were later transcribed. The transcripts were arranged and analyzed. The data were divided into a training set (79 discussions; 90%) and a test set (9 discussions; 10%) before data mining was performed. The training set was used to construct a training model, and the test set was employed to examine whether the proposed model correctly predicted creativity in the students. K-means clustering was used to cluster the language in the discussion content. The level of creativity of each student was correctly predicted by the model, which can be used by teachers to provide feedback and support in a timely manner for triggering different thinking in students to enhance his or her creative thinking. The proposed model can thus identify level of creativity and assist both teachers and students.

Introduction

In a highly competitive global market, industries urgently need talented people who can innovate and engage in self-design. To meet the needs of industry and cultivate talented workers, engineering education courses in most schools focus on developing students' abilities to collect, analyze, interpret, and apply detailed information, as well as to create, reflect, and adapt to change. Therefore, engineering education programs should give importance to how they can equip students with adequate innovation skills.

In creativity education, the interpretation and opinions of the definition of creativity vary with fields and perspectives [1]. In short, creativity is defined as the ability to create with an innovative nature [2]. It is a characteristic and ability possessed by people rich in creativity [3]. Most scholars usually judge the possession of creativity from the perspective of finished works [4]-[7]. However, the evaluation of creativity should not be limited to results [5]. Actual portfolio records, which are made during learning and evolve over time, can help with understanding the factors that influence creativity, and these factors can be used to improve engineering education.

With the development of information technologies, the way we store information has changed from paper storage to digital storage. Digital information can serve as an effective and reliable record of a learner's learning outcome. Digital learning portfolios are more effective than analog portfolios for storing and managing data [8]. Learning portfolios include assessment tools with multiple meanings. In addition to providing actual behavioral approaches, the abundant information and value hidden in learning portfolios also reflect personal characteristics and cognitive processes [9]. Cognitive processes refer to a number of tasks the brain does continuously. They are procedures in charge of processing all the information we receive from the environment [10]. Situational meanings and developmental contexts can be effectively identified through structural analyses and investigations and can assist students in expanding their range of knowledge [11].

This study collected 1 year of records of discussions and interactions on the Moodle learning platform among students on two college courses (Computer Science and Engineering). The discussions and interactions were filmed and recorded in a backend database and were later transcribed. The transcript data were arranged and analyzed using data mining. The data were divided into a training set and a test set. The training set comprised 79 discussions (90%), and the test set comprised 9 discussions (10%). The data of the training set were used to construct a model, and the data of the test set were used to examine whether the proposed model correctly predicted creativity in the students. If the level of creativity of each student can be predicted according to the language used in the discussions, teachers can provide feedback and support in a timely manner to trigger different thinking in a student for enhancing his or her creative thinking.

Furthermore, a k-means clustering analysis was performed to divide the contents of the discussions into clusters for investigation. Differences in cognitive processes caused by differences in creativity, as displayed in the discussions and interactions, served as the basis for teacher feedback and support to promote self-reflection and enhance creative thinking. This study shows that recording and analyzing the discussions, thought processes, and interactions between students offer opportunities to improve the teaching environment, develop appropriate behavioral approaches, help students make interdisciplinary connections, and improve learning outcomes.

Learning System

Figure 1. Interface of Moodle learning system

This study built upon past research and used action research methods to identify appropriate adjustments to activity planning and guidance methods, with the objective of developing cooperative interaction and creative thinking abilities in students over one academic year [12]. The Moodle learning platform was employed to enable students to interact regarding class projects. A modular structure, divided into a core module and a plug-in module, was adopted to establish the platform. The plug-in module was interfaced with the core module to add or expand functions on the platform. This module structure is flexible and useful and can meet the needs of various courses.

In accordance with project-based learning and the substitute, combine, adapt, modify, put to other uses, eliminate, reverse (SCAMPER) teaching strategy, the plug-in module (activity module) was integrated with the Moodle learning platform. The web server used Apache and PHP syntax, and the database employed the MySQL associative database. Furthermore, to enable the students to engage in synchronous video conferencing on the platform, a remote video conferencing kit was installed for interaction through JoinNet at any time during activities. Therefore, the students could use a single learning platform and take part in course activities to meet their learning needs. The students' behaviors and interactions on the platform were recorded in the backend database until further analysis.

The platform's interface and functions are shown in Figure 1. In addition to providing basic relevant functions, the platform provided a guide page for the execution of five activity stages: preparation (P), implementation (I), publication (P), evaluation (E), and revision (R). The students could meet the requirements of the various stages through guidance provided by the teachers in a timely manner. Moreover, diverse learning tools were provided in the five stages to encourage the students to participate in class activities and engage in class discussions. The students could find solutions to problems, expand their understanding, and develop their individual and teamwork-related skills through brainstorming and interaction with classmates.

Research Design

Participants

The research subjects were junior college students enrolled in Computer Science (1) and Engineering (2) courses at the College of Engineering at a national university in Taiwan. There were 46 students who were divided into groups of 3 or 4 (a total of 14 groups). Each group engaged in project-based learning and SCAMPER teaching activities through the Moodle learning platform. The media on the learning platform enabled the students to study at their convenience and urged them to engage in various activities that demanded creativity and critical thinking. To ensure that the project was successful, the students' grades from the experimental activity were included in their school grades.

Experimental procedure

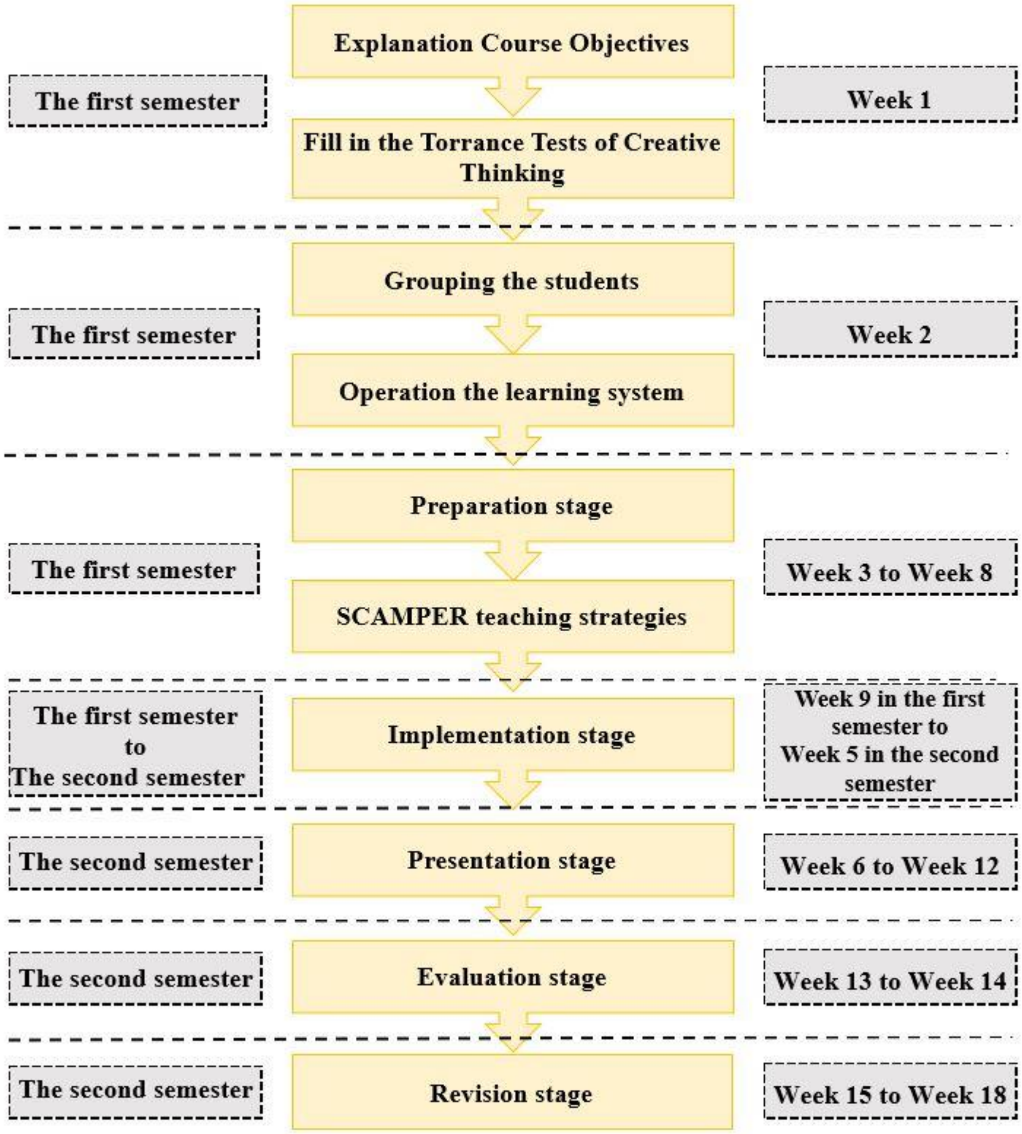

Figure 2. The experimental procedure

The Computer Science course was held in the first semester, and the Engineering course was held in the second semester. Each semester was 18 weeks long (two classes every week). In Week 1 (semester 1), the teacher explained the course objectives, teaching procedures, activity framework, and assessment methods (including grading), which included a detailed explanation of the project-based learning and SCAMPER activities. Each student completed the Torrance Tests of Creative Thinking (TTCT); TTCT assessment was employed to understand each student's level of creativity. The students were divided into groups and began using the platform in Week 2. They were given time to learn the different features and functions of the platform.

The students engaged in project-based learning activities from Weeks 3–8 (first semester)—the preparation stage—using the various features and functions on the platform to learn, engage with other students, discuss seminars, clarify the concepts of problems, and correct the concepts of problems through data collection. The SCAMPER teaching strategies were also introduced at this stage. Thinking perspective and direction were altered through the seven SCAMPER cognitive processes to enable students to innovate and increase their knowledge.

The implementation stage started in Week 9 of the first semester and finished in Week 5 of the second semester. During this stage, the students developed projects in accordance with the procedures and frameworks established in the first stage through interaction and cooperation with other students through the platform. Multiple perspectives were identified by the students, and their problem-solving skills improved. The presentation stage occurred in Weeks 6–12 in the second semester; each group of students used the synchronous conferencing function to present project reports. The reporting method and content were presented without limitation according to the discussions that took place in each group. Mutual observations and project reports were shared on the platform between the groups and peer feedback and suggestions were given. The feedback and suggestions helped the students to identify what they needed to improve and further prompted self-reflection and self-monitoring. The evaluation stage occurred in Weeks 13 and 14. The evaluation not only included learning outcome assessment but also an assessment of the entire learning process, including group participation, problem-solving skill, and knowledge construction up until that point. The suggestions and evaluation results were uploaded to the learning platform. The revision stage occurred in Weeks 15–18. During this stage, the students engaged in self-reflection and discussion in response to the feedback they received from their teachers and peers and through the marked project report. The students then corrected their project reports and uploaded them to the learning platform. The whole experimental procedure is shown in Figure 2.

Assessment tools

(1). Torrance tests of creative thinking

The TTCT was developed by Torrance et al. at the University of Minnesota in 1966. It is the most comprehensively applied creativity test and is applicable to people of all ages. It is composed of a language-related creative thinking test, an image-related creative thinking test, and a creative thinking test on sounds and vocabulary. The tests are performed as games; therefore, the testing process is enjoyable. Because the subjects in this study were over the age of 18, this study adopted the version for adults.

(2). Discussion contents

All synchronous and asynchronous discussions and processes of the students on the learning platform were generalized, arranged, and analyzed. A support vector machine (SVM) was used to arrange the data for developing the prediction model. Furthermore, the data were divided into a training set and a test set, with the test set employed to evaluate the predictive effects of the proposed model. K-means clustering analysis was used to understand the connections between cognitive concepts and the frequently used words of learners with high and low levels of creativity.

Research Results

Analysis of the TTCT

The TTCT comprised three activities that were each completed in 3 minutes. The explanation and test time of each activity lasted approximately 15 minutes. The scoring of the test results was divided into four dimensions totally. The results of a single-sample t-test are presented in Table 1. The differences in the four dimensions (fluency, originality, elaboration, and flexibility) all reached significance, indicating that there were differences in the thinking abilities between students with high creativity and those with low creativity. Furthermore, there were differences in understanding differences in abilities to identify the core of problems, perform analysis, evaluate, and think systematically.

Table 1. The analysis results of the TTCT

Dimensions	**N**	**M**	**SD**	**t**	***p***
fluency	46	11.98	1.88	43.22	.000*
originality	46	5.37	1.45	25.10	.000*
elaboration	46	13.87	3.81	24.69	.000*
flexibility	46	3.02	.856	23.94	.000*

$^{*}p < .05$

Analysis of the predictive model

The synchronous and asynchronous discussion processes and contents for each group at each stage were collected and arranged, and the discussions were transcribed (a total of 88 interactions). Because text is nonstructural data, the original text had to be converted into numerical form. This process was divided into word segmentation and word frequency. This study used the CKIP Chinese word segmentation system developed by Academia Sinica [13]. Term frequency–inverse document frequency (TF–IDF) was used to calculate word frequency. TF–IDF evaluates the level of importance of a word in documents within a document set or a corpus.

This study used an SVM to perform data mining. The training set comprised 79 discussions (90%), and the test set comprised 9 discussions (10%). The data of the training set were used to construct the model, and the data of the test set were used to examine whether the proposed model predicted creativity in the students. Accuracy was used as the criterion employed to evaluate the model. The analysis was performed by using free software (RapidMiner) shown in Figure 3.

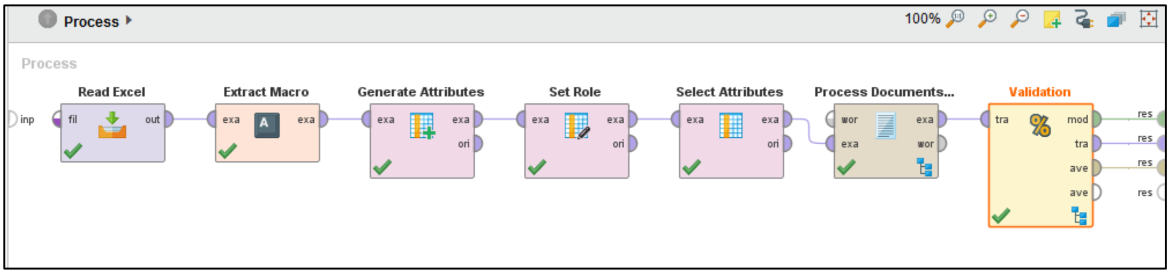

Figure 3. The analysis process in the RapidMiner

According to the results, the accuracy of the proposed model was 76.11%. Therefore, the teacher would be able to apply this model in subsequent courses to predict a student's level of creativity from their participation in discussions on the platform. Furthermore, the teacher could adjust their teaching strategies to help the students with their creative thinking in a timely manner.

Analysis of cognitive concept connections

The students were divided into students with high and those with low creativity according to the scores from the TTCT (Half scores for each of the four dimensions) to understand the differences in the cognitive concepts expressed between the two groups of students. Afterwards, k-means clustering analysis was employed to divide the data into clusters. According to the results, the discussion contents could be divided into two major clusters, high creativity (cluster 0) and low creativity (cluster 1), as shown in Figure 4. The high creativity cluster comprised 64 discussions, whereas the low creativity cluster comprised 24 discussions. The six most frequently used keywords in each cluster were as follows: sever, discussion, connection, function, report, and framework (high creativity group); and teacher, one, search, time, general, and data (low creativity group).

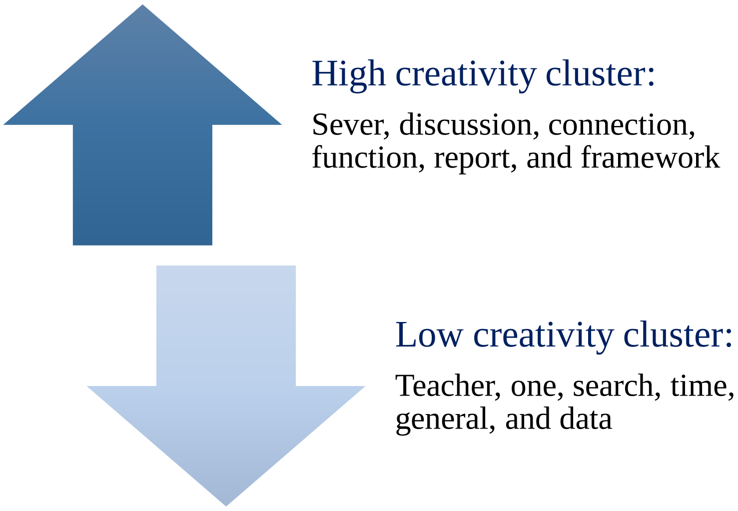

Figure 4. The discussion contents of two groups

The clustering results for the vocabulary used in the interactions and discussions between the students revealed that the students with low creativity used more shallow language. Furthermore, the words and phrases they used in their discussions during the project design and practice stages were less specific than those used by the high creativity group. During the entire activity, they were more passive and were not strong at expressing their opinions. The students with high creativity tended to be more specific during the interactions and discussions. They were able to report their projects in detail and investigate the framework and functions of the platform. Furthermore, they were more active and aggressive during the entire activity, more willing to share their ideas, and more open to others' opinions and suggestions.

Conclusion and Future Studies

Engineering courses in most schools aim to cultivate outstanding interdisciplinary skills and problem-solving abilities in students. Engineering education thus places importance on providing students with adequate courses and activities to develop these abilities, cultivating new talent to meet the needs of industry. However, creativity is investigated from a single dimension in most courses, usually by assessing a student's final products. Few studies have examined how to recognize and develop creativity or attempted to predict a learner's level of creativity from his or her behavior in activities. Understanding how people learn and develop their creativity would be beneficial to relevant research and in guiding behavior. Therefore, this study used Moodle as the learning platform and introduced project-based learning and SCAMPER teaching strategies as the course foundation. This study used the activity guidance and assistive functions on the platform to help group members interact with and learn from other students. Furthermore, this study developed a creativity-prediction model through data collection and analysis. The proposed model can help teachers identify learners with high creativity and those with low creativity and understand the difference between them.

According to the results of the TTCT, there were differences between the students with high creativity and those with low creativity in four dimensions (fluency, originality, elaboration, and flexibility). The implementation of project-based learning activities and SCAMPER teaching strategies should improve the learning outcomes of students in terms of their thinking processes and ability to cooperate with other people.

The content of peer interactions were processed using word segmentation and word frequency analysis, and SVM was used to organize the data. Furthermore, this study used training and test data to construct and evaluate the proposed predictive model, which was discovered to have an overall accuracy of 76.11%. Teachers can apply this predictive model in learning activities to evaluate their students' level of creativity and assist their students in a timely manner. The results of k-means clustering analysis revealed that students with high creativity were more active and more willing to share their ideas, which also tended to be more profound and specific compared with those presented by the students with low creativity. This finding is consistent with a study by Collette and Chiappetta who discovered that learners with more active curiosity and desire for knowledge more frequently employ their imagination, reasoning, thinking, and problem-solving abilities [14]. Such learning behavior denotes creative thinking activity. Therefore, future studies can use this predictive model to guide learners with low creativity to exchange ideas with other students and improve their creative thinking skills.

This study is ongoing and will evaluate the stability and accuracy of the predictive model in the future. Moreover, a more in-depth investigation will be performed to examine different personality traits and learning behaviors.

Acknowledgements

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