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A Project-Oriented Capstone Course for Creative Engineering Education

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A Project-oriented Capstone Course for Creative Engineering Education

Abstract

The project-oriented capstone course has been required as an important criterion for international accreditation of engineering degree programs under Washington Accord. In addition to provide an opportunity for university students to apply what they have learned in their school years to actual engineering problems, the project-oriented capstone course also trains students how to work as a team. Although fundamental laboratories courses are provided to establish students' hands-on experiences and consolidate connection between theoretical background and practical implementation, students still have difficulties to incorporate multidisciplinary knowledge into solving a real engineering problem in a more systematic way. Therefore, a one-year project-oriented capstone course, Special Topics in Mechanical and Electro-Mechanical Engineering, has been available at the junior year for undergraduate students in the Department of Mechanical and Electro-Mechanical Engineering, National Sun Yat-Sen University (NSYSU), Taiwan.

In 2003, Ministry of Education (MOE) of Taiwan (Republic of China) revealed the White Paper on Creative Education. Since then, a series of projects led by MOE and the Ministry of Science and Technology (MOST) aiming at rooting imagination and creativity in education contents were promoted on different educational levels. In order to fully understand the effect on creative thinking of students, the New Creativity Test (NCT) proposed by Wu et al. in 1988, consisting two parts: verbal and figural, was applied to participating students before and after taking this project-oriented capstone course. Measures in four dimensions, including fluency, flexibility, originality, and elaboration, were conducted based on paired *t*-tests. The NCT-Verbal has the first three dimensions; however, The NCT-Figural owns all four dimensions. There were 19 participants in total, 18 males and 1 female accepting the NCT. All of them were junior undergraduate students. For the NCT-Verbal, the results showed significant difference between pre-test and post-test on fluency, flexibility, and originality. Nevertheless, similar outcome was not reflected on the NCT-Figural. The paired *t*-test results for the NCT-Figural indicated no significant connection between pre-test and post-test in all four dimensions. As a result, it can be concluded in the preliminary study that the project-oriented capstone course has positive effect on creative thinking in verbal aspect despite of no significant influence on creative thinking in figural aspect.

Introduction

Problems in engineering fields are usually complex, ill-defined, interdisciplinary, and do not have standard answers. All kinds of generic knowledge learned from schools may not be directly applied to engineering problems in real world without sufficient practices and experiences. As a result, problem-based learning (PBL) has been a widespread teaching method in engineering disciplines due to its connection with real-world engineering contexts. Through the problem-based learning process, students can develop better understanding of engineering fundamentals because they find the information for themselves and actively apply the information to solve the

problems.[1] About a dozen years ago, a PBL curriculum in aerospace engineering was organized to form a complete product life cycle, i.e., conceiving, designing, implementing, and operating (CDIO).[1] In addition, for the purpose of shortening the route to real engineering world in front of graduates, it is clearly beneficial to further facilitate students making flexible use of engineering knowledge they have assimilated in the classes and to strengthen the link between academic theorems and practical hands-on applications. Following this trend, a curricular and pedagogical model for teaching multidisciplinary design to senior undergraduate students was presented.[2] As a result, a project-oriented capstone course at junior or senior year of undergraduate programs has been strongly required to balance the theory and practice in engineering education.[3] Besides, an approach for engineering curriculum integration in capstone design courses to integrate the engineering design with all relevant engineering and non-engineering disciplines was also raised.[4] It was pointed out that learning through projects has a positive effect on student content knowledge and the development of skills such as collaboration, critical thinking and problem solving, increases their motivation and engagement.[5]

Engineering projects more or less contain the elements of creativity and innovation. It is expected that the levels of creative thinking before and after taking the project-oriented capstone course should display considerable difference. The New Creativity Test developed by Wu et al. provides a cognitive approach for creativity study.[6] This test is similar to the Torrance Tests of Creative Thinking (TTCT), the most widely applied instrument for identification of the creativity.[7] The NCT also consists of two parts, verbal and figural, but with contents of Chinese culture such as chopsticks and the pattern of a Chinese character. Therefore, it has been a popular creativity test within Chinese societies.[8-9] Recently, an interesting study using the NCT-Verbal, a different figural creativity test, and an insight problem test on undergraduates in Macau indicated that there was no significant correlation between insight and creativity in both verbal and figural forms.[10]

Taiwan is a small island located at the western Pacific Ocean. In order to stand on the world platform, Taiwan greatly relies on human resources more than other countries under the circumstance lacking of natural resources. Therefore, the Ministry of Education in Taiwan has promoting cultivation of creativity and innovation in all levels of schools including fundamental and higher educational ones for more than one decade. The white paper on creativity education by MOE announced six action plans through 2008.[11] According to The Global Competitiveness Report 2014-2015 released by the World Economic Forum, Taiwan has ranked as top 10 in 144 economies in the world in terms of the innovation index.[12] Under the umbrella of the Imagination Research Projects Program raised by the Ministry of Science and Technology, the College of Engineering in National Sun Yat-Sen University is responsible for conducting a three-year integrated project entitled “Research on Innovations in Engineering Curriculum and Modularized Technology Special Topics.” This integrated project covers all departments and institutes in the college and tries to analyze the development of creativity in selected courses in the College of Engineering. This project consists of six sub-projects as illustrated in Fig. 1. Sub-projects I to V are performed by individual engineering departments and institutes; however, sub-project VI is conducted by a Professor in Institute of Education to carry out class survey and creativity analysis. This project starts from December 2014 and should be finished in November 2017. Every department and institute in College of Engineering chose one or two courses as target subjects for this project.

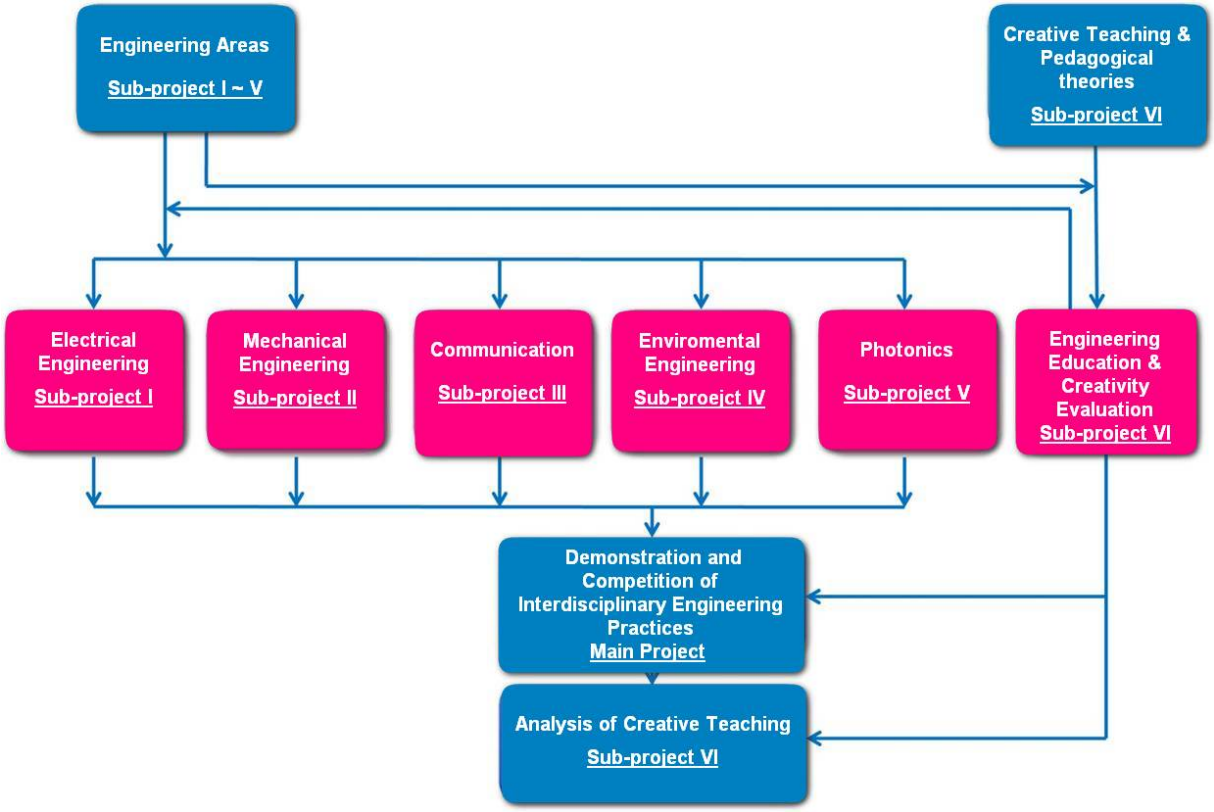

Fig. 1. Framework of the integrated innovation curriculum project of "Research on Innovations in Engineering Curriculum and Modularized Technology Special Topics".

Among all departments and institutes of the college, Department of Mechanical and Electro-Mechanical Engineering is the second largest educational unit. There are about 110 new students as freshmen in our department each year. Comparing with traditional mechanical engineering departments, curriculum in our department is designed with more emphasis on electronics, automation, and nano fabrication. In order to reach higher standard of educational quality by complying with the requirement on capstone courses for international accreditation under Washington Accord, a one-year project-oriented capstone course, Special Topics in Mechanical and Electro-Mechanical Engineering, has been available for the third year students in the department. This course joined the integrated innovation curriculum project as the target course for the sub-project II. This paper summarizes the first year preliminary results on creativity analysis of the sub-project II for this integrated innovation curriculum project.

Development of the Project-oriented Capstone Course

The courses developed in engineering departments of universities usually aim at strengthening and expanding both fundamental theories and knowledge. Although some engineering courses are designed from the perspective of applications, weak linkage to future practical workplace still exists and the processes of re-training and re-education become inevitable for fresh graduates after getting their first jobs. In order to bridge between academic theorems and applications in

real world, a project-oriented capstone course is established at the third year of the undergraduate program in the department. By conducting the projects, participating students have to integrate individual specialties to reach their common goal within a fixed time span. At the same time, the department is able to reach international standards of educational quality certified through accreditation of IEET (Institute of Engineering Education Taiwan), a Full Signatory of the Washington Accord.

Course Structure

Basically the project-oriented capstone course, "Special Topics in Mechanical and Electro-Mechanical Engineering", lasts for two semesters at the third year of the undergraduate program. This course focuses on providing students an opportunity to develop and accumulate interdisciplinary skills and experiences by incorporating knowledge and techniques they have learned from the classes into an academic or industrial case study. Under the atmosphere of current education in Taiwan, more than two thirds of the undergraduates tend to go to graduate schools for advanced studies after they obtain their Bachelor degrees. As a result, most students have strong intention to take the capstone course as a pre-graduate-school project for future research work.

Based on five research groups developed in the department including thermo-fluids, solid mechanics, control, design and manufacturing, and micro-nano systems, the department provides six compulsory laboratory courses: machine shop, thermo-fluids laboratory, material testing laboratory, electronics laboratory, control laboratory, and MEMS fabrication processing laboratory in the undergraduate program. With the basic training in those laboratory courses, students are able to face hands-on requirements and challenges the capstone course may bring about.

The project-oriented capstone course is designed to stimulate students to incorporate professional expertise knowledge, hands-on experiences and skills, as well as creativity and imagination into projects with authentic engineering problems. Guidelines of this capstone course established by the department are summarized as follows:

1. The project not only emphasizes on its scientific and engineering contents, but some important features connecting to future work environment such as creativity and innovation, risk assessment, communication, conflict coordination, project management, and teamwork.
2. The project needs to be supervised by faculty members in the department.
3. The project has to be conducted as a group with maximum five and minimum three students to fulfill the requirement for teamwork.
4. At the beginning of the course, each group needs to submit a project proposal, which should clearly state motivations and objectives, approaches and methods, and time schedule plan to achieve the goal of the project.
5. Students also need to manage their own project budget and expenditure.
6. Project achievement has to be displayed and demonstrated at the end of this course. After completion of the course in one-year span, every group must participate in the annual exposition and competition of the capstone course. Both written report and poster presentation are required.

Students and Faculty Involvement

In 2014-2015 academic year, the first pilot year for the project-oriented capstone course, a detailed time schedule as shown in Table 1 was settled to allow both professors and students to follow the same pace with the department. Twelve out of thirty-one faculty members provided versatile project topics covering all research fields in the department. There were 46 junior students in total taking this course. They were divided into 17 groups and each group worked on an independent project topic.

For the purpose of letting students stay on their personal research interests, each group made a priority list for at least three project topics at the beginning. The department did its best to match the groups and projects so that most students had strong motivation and interest on their projects. Once the final list of the paired groups and projects was announced, the students were required to talk to their supervisor and completed an interview form. The interview form not only reconfirmed the project topic and student members, but also drafted preliminary plan to accomplish the project including the progress chart, duty assignment, and budget estimation.

Table 1 Time schedule for the 2014-2015 project-oriented capstone course.

Date	Things to do
19 Sep. 2014	Orientation for the project-oriented capstone course and announcement of the participating projects
19-25 Sep. 2014	Submission of the lists of group members and projects priority
26 Sep. 2014	Announcement of the final list for the paired groups and projects
Oct. 2014	Submission of the completed interview form after group members talk to their supervisor
Jan. 2015	Project progress report for the first term
Feb. 2015	Application to MOST Undergraduate Research Project Program
May 2015	Application to NSYSU Encouraging Undergraduate Research Project program
Jul. 2015	Draft submission of the project report
Sep. 2015	Submission of a 4-page project summary and a poster
Oct. 2015	Annual exposition and competition
Dec. 2015	Submission of the final project report

Sufficient fund, as a financial support for possible cost of materials, instruments, and manufacturing while conducting the projects, is a key issue to make the capstone course work properly. The Undergraduate Research Project Program sponsored by the MOST is the main

resource to acquire the fund. A representative student of each group needs to be responsible for writing the project proposal for application. Apparently, not every group can obtain the research grant from the MOST. Fortunately, a second option, the Encouraging Undergraduate Research Project Program provided by the Office of Research Affairs of our university, exists to help students conducting their projects. In addition, most faculty members are willing to subsidy their research grand from other research projects to the project-oriented capstone course. As a result, all 17 projects in the course were going well and smoothly in terms of the fund collecting.

At the end of this course, each group has to attend the annual projects exposition and competition. A 4-page project summary needs to be submitted for the judges in competition. Poster display, exhibition, and oral presentations are required to demonstrate the achievement of the projects. Awards and certificates of merit are prepared to praise the achievement of the winners.

The Creativity Evaluation Test

The TTCT, first developed by E.P. Torrance in 1966, has been the most widely used test of creativity and is the most referenced of all other creativity tests. It consists of two parts, the TTCT-Verbal and the TTCT-Figural, and each one has two parallel forms, A and B. The TTCT-Verbal test has five subsets: ask and guess, product improvement, unusual uses, unusual questions, and just suppose, to access three mental characteristics including fluency, flexibility, and originality. In TTCT-Verbal Form B, examinees need to present as many usages as possible for an empty jar. The TTCT-Figural test has three subsets, picture construction, picture completion, and lines. In "lines" of the TTCT-Figural Form A, drawing has to be made based on thirty pairs of parallel lines and is scored on fluency, flexibility, originality, and elaboration.

The New Creativity Test, also consisting of two parts, a verbal test and a figural test, was chosen for creativity evaluation in this study. The NCT, as a Chinese version of the Torrance Tests of Creative Thinking, evaluates participants' abilities of verbal and figural creativity. The verbal test asks the participants to list possible uses of bamboo chopsticks, and the figural test requires the participants to draw pictures using given different sized pattern of "人", which is a Chinese character meaning of people. Each of the tests needs to be accomplished in 10 minutes. The scoring indices of both tests include fluency, flexibility, and originality; however, an extra score index of elaboration is offered by the figural test.

Because both tools, the bamboo chopsticks and the graphic pattern of a common Chinese character, reflect Chinese contexts, the NCT is able to capture the creativity potential of Chinese participants. In the report written by Wu et al., there were 2,311 students from elementary schools to graduate institutes in Taiwan involved in the test.[6] Inter-rater reliability analysis was done by twenty tests evaluated by different raters. The resulting Kendall's coefficients of concordance on fluency, flexibility, and originality reached 0.93 in both verbal and figural tests. As for the validity, based on the criterion of "empty jar" in Verbal B of the Torrance Tests of Creative Thinking, the significant correlations for fluency and flexibility were 0.7 and 0.62. Furthermore, according to the criterion of "lines" in Figural A of the Torrance Tests of Creative Thinking, the correspondingly significant correlations for the fluency, flexibility, and originality were 0.75, 0.63, and 0.57, respectively. To sum up, it can be concluded that the NCT is an appropriate instrument for creativity evaluation with good reliability and validity.

Preliminary Creativity Evaluation of the Capstone Course

There were 19 participants in total, 18 males and 1 female, accepting the NCT. All of them were junior undergraduate students. Both pre-course and post-course tests were conducted. Table 2 lists the means and standard deviations of both pre-test and post-test in all dimensions of the NCT Verbal and Figural forms. It appears that the post-tests presented improvement on fluency, flexibility, and originality in the NCT-Verbal; but not in all dimensions of the NCT-Figural. In order to understand the effect on creative thinking of participating students after taking the project-oriented capstone course, paired *t*-tests were also performed and the results are presented in Table 3. The last two columns in Table 3 indicate the *t*-test significance and the effect size *d*, respectively. For the NCT-Verbal, the results exhibited significant difference between the pre-test and post-test in all dimensions: fluency, flexibility, and originality. Nevertheless, similar outcome was not reflected on the NCT-Figural. The paired *t*-test results for the NCT-Figural indicated no significant connection between pre-test and post-test on fluency, flexibility, originality, and elaboration. Consequently, it can be concluded in the preliminary study that the project-oriented capstone course has positive effect on creative thinking in verbal aspect despite of no significant difference on creative thinking in figural aspect.

Table 2 Dimensions, means, and standard deviations of pre-test and post-test for the NCT-Verbal and the NCT-Figural.

New Creativity Test	Dimension	M_{pre}	SD_{pre}	M_{post}	SD_{post}
Verbal form	Fluency	8.95	5.67	13.21	6.51
	Flexibility	6.58	3.32	8.05	3.27
	Originality	5.37	5.79	10.32	7.21
Figural form	Fluency	11.63	4.62	12.84	5.27
	Flexibility	8.05	2.59	8.84	2.95
	Originality	9.32	5.58	10.58	6.62
	Elaboration	5.74	4.19	4.37	2.85

Conclusions

The project-oriented capstone course entitled “Special Topics in Mechanical and Electro-Mechanical Engineering” has been offered for junior undergraduate students in the department to equip them with the problem-solving skills, teamwork character, and project management experience for future real world requirements. In order to investigate if the improvement on creative thinking can be achieved by joining the project-oriented capstone course, the NCT was performed on 19 participating undergraduate students at the moments before and after taking the course. According to the NCT-Verbal results, the post-tests indicated improvement on fluency, flexibility, and originality; however, similar outcome was not shown in the tests of the NCT-figural. The paired *t*-tests confirmed significant difference between the pre-test and post-test in

all dimensions: fluency, flexibility, and originality on the NCT-Verbal, but no significant connection for the NCT-Figural. It can therefore be summarized that the project-oriented capstone course imposes positive effect on creative thinking in verbal form regardless of no significant difference in figural form.

Table 3 Dimensions, means, standard deviations, *t*-test significances, and the effect size *d* of the difference between pre-test and post-test for the NCT-Verbal and the NCT-Figural.

New Creativity Test	Dimension	$M_{post\text{-}pre}$	$SD_{post\text{-}pre}$	$t_{post\text{-}pre}$	d
Verbal form	Fluency	4.26	4.90	3.80**	0.70
	Flexibility	1.47	2.48	2.59*	0.45
	Originality	4.95	5.82	3.71*	0.76
Figural form	Fluency	1.21	4.48	1.18	0.24
	Flexibility	0.79	2.57	1.34	0.28
	Originality	1.26	4.87	1.13	0.21
	Elaboration	1.37	2.63	2.27*	-0.38

** $p < 0.001$
* $p < 0.05$

Bibliography

1. Brodeur, D. R., P. W. Young, and K. B. Blair, "Problem-Based Learning in Aerospace Engineering Education," in *Proc. 2002 American Society for Engineering Education Annual Conference & Exposition*, 2002.
2. Miller, R. L. and B. M. Olds, "A Model Curriculum for a Capstone Course in Multidisciplinary Engineering Design," *Journal of Engineering Education*, vol. 83, no. 4, pp. 1-6, 1994.
3. Dutson, A. J., R. H. Todd, S. P. Magleby, and C. D. Sorensen, "A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses," *Journal of Engineering Education*, vol. 86, no. 1, pp. 17-28, 1997.
4. Noble, J. S., "An Approach for Engineering Curriculum Integration in Capstone Design Courses," *Int. J. Engng. Ed.*, vol. 14, no. 3, pp. 197-203, 1998.
5. Chandrasekaran, S., A. Stojcevski, G. Littlefair, and M. Joordens, "Learning through Projects in Engineering Education," in *Proc. 40th SEFI Annual Conference*, 2012.
6. Wu, J. J., C. H. Kuo, W. W. Lin, S. H. Liu, and Y. H. Chen, *Development of a New Creativity Test for Use with Students in Taiwan*, Taipei, Taiwan: Ministry of Education, 1998.
7. Torrance, E. P., *Norms Technical Manual: Torrance Tests of Creative Thinking*, Lexington, MA: Personnel Press, 1974.
8. Forrester, V. and A. Hui, "Creativity in the Hong Kong Classroom: What is the Contextual Practice?" *Thinking Skills and Creativity*, vol. 2, pp. 30-38, 2007.
9. Wu, J. J. and D. Albanese, "Asian Creativity, Chapter One: Creativity across Three Chinese Societies," *Thinking Skills and Creativity*, vol. 5, pp. 150-154, 2010.

10. Tsai, K. C., "Creativity and Insight: A Case Study of Chinese Undergraduates in Macau," *British Journal of Psychology Research*, vol. 3, no. 2, pp. 12-18, 2015.
11. MOE (Ministry of Education), *White Paper on Creative Education*, Taipei, Taiwan: Ministry of Education, 2002.
12. Schwab, K. ed., *Global Competitiveness Report 2014-2015*, World Economic Forum, 2014.