The Development and Implementation of the Technological Creativity Course: An Interdisciplinary Approach

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Abstract: The teachers' experiences on developing an interdisciplinary course, "Open-Ended Creative Mechanical Engineering Design," for technological creativity cultivation are discussed in this paper. The paper will cover three essential aspects of the course: (1) the rationale to incorporate technological creativity in engineering education, (2) the design of the course, including hands-on activities, instructional strategies, and supplemental materials on technological creativity, and (3) the effects of interdisciplinary teaching on students. This course is jointly designed and taught by four professors of interdisciplinary backgrounds: creative learning, thermo-fluid, design, education, and computer network based learning. The learning modules developed include: (1) utilizing mechanical engineering design procedures, i.e. brainstorming, evaluating, and implementing the team project; (2) experiencing the four phases of technological creativity problem solving, i.e. preparation, incubation, illumination, and implementation; and (3) executing the eight essential procedures of a hands-on creativity contest and project design. The course has been developed and taught for two years by engineering professors. Since this year, quantitative and qualitative data of student interviews, questionnaires, classroom observations and discussions on web-bbs have been collected and analyzed with the participation of faculties in education in order to understand learning difficulties and to look for inspiration of improvement.

Keywords: Interdisciplinary, creativity, project-based learning, technological

1. The importance of cultivating technological creativity in engineering students

Traditional education for engineering students focuses on the indoctrination of domain knowledge in class. Most problems in class given to students are well defined with only one correct solution. Under the current engineering training, the students are asked to solve the "text book" problems, which in general are simple, formulated in particular forms and have standardized approaches and answers. In industry, however, engineers often face complicated problems with no immediate and absolute answer. Hence, engineering graduates often find what they have learned in college are not practical for solving industrial problems.

In reflecting such challenge, the course of "Open-Ended Creative Mechanical Engineering Design" was offered in the Department of Mechanical Engineering at the National Central University. The purposes of this course are:

(1) to inspire students' technological creativity via appropriate leaning modules,
(2) to train students to solve open-ended industrial problems, and
(3) to emphasize the importance of teamwork and the skills of communication in the industrial working environment.

2. The modules of creative learning

2.1 The implementation of interdisciplinary approach

The class is developed to inspire students' technological creativity, and to give students the opportunity to solve open-ended problem within industrial working environment [1]. Based on the experiences for the past two years, we perceive the need for professionals from other disciplines to stress the importance of communication as well as teamwork skills for engineering students. More importantly, a scientific evaluation of the course and its effects on the students' learning of technological creativity must be done in cooperating pedagogical experts with engineering ones. The analysis of student outcomes can give information about the success of the innovative course in achieving our objectives.

But the question is: how can professors with engineering background to integrate their technical capabilities with an educational-oriented perspective? Engineering teachers may understand the cognitive and emotional conflict that students encounter, but couldn't verify their teaching approaches in order to take into account students' different learning styles. Besides, an engineering course taught by faculty without an engineering background face a challenge of given students the new perspectives without accommodating the technology orientation of engineering students. The contents are designed to develop students' competence in the following areas:

(1) Engineering design process
(2) Designer and teamwork
(3) Basic principles of creative problem solving (CPS) process
(4) Hands-on learning activities to inspire creativity

The curricula contain16 learning activities on the following 10 topics:

◆ **Content Outline**	◆ **Learning activities**
◆ Orientation to technological creativity	● Use cases to introduce the importance of creativity to industrial technology
◆ Cognitive process of creative problem solving	● Present a design problem to illustrate four stages of CPS skills
◆ Thinking styles and contexts for developing creativity	● Administer Sternberg's Thinking Style Inventory to illustrate the characteristics of each thinking style
◆ Creative personality and teamwork experience	● View a film to describe the characteristics of creative people. ● Interview team members and identify their specialties
◆ Principles and strategies of lateral thinking	● Analogy ● Simulation activities
◆ Conventional engineering design process	● Discuss basic rules for invention ● Apply above rules to improve the design of commercially available items
◆ Problem solving in mechanical design	● Brainstorm potential ideas for contest via WWW ● Use drawing/sketches to design a working model
◆ Problem solving in electric circuits and electronics	● Problem solving a case to illustrate the electric & electronic concepts relate to project design
◆ The creativity contest (by individual)	● Let the show begins! ● Peer-evaluate and select the top 3 most creative vehicles
◆ Research for proposal (RFP) of creative project design (by group)	● Develop a RFP based on all information gathered ● Make oral presentation to class using Powerpoint

The materials included in this table are developed to foster engineering students' technological creativity. Specifically, we wish to demonstrate how problem solving and engineering procedures can be closely integrated and taught and what are the necessary knowledge and skills to enhance students' ability to become creative as well as effective problem solvers. For instance, teachers from engineering field contribute to enhance students' domain knowledge of technological creativity in the engineering process, whereas teachers from education field deal with the challenge of providing a range of teaching strategies fit for its purpose and the assessment of student design performance.

In addition to the domain knowledge, the courseware also contains pop quiz, which will require trials, observations, comparisons, and self-examinations before a reasonable solution can be revealed. Through such provocation, students can shed off their deeply rooted question-and-quick-solution type of reflective learning style, and start the evolution into a seasoned engineer who would test, observe, incubate, and innovate. After all, engineering education is not so much of some limited amount of domain knowledge, but, more importantly, a life long learning habit and the intrinsic motivation to innovate and to excel for better humanity.

2.2 Creative problem solving process

Creative problem solving [2] is a well-defined methodology that encourages students to brainstorm and generate their sketchy ideas, analyze the ideas, implement their plan, and eventually evaluate the plan. In order to enhance students' creative thinking skills, and social interaction skills, as well as communication skills. students are asked to solve the following dilemma that are intended to provide both the analytical skills and teamwork experience needed to solve design problems.

Heinz dilemma:

In Europe a woman was near death from a very special kind of cancer. There was one drug that the doctor thought might save her. The drug was expensive to make, but the druggist was charging ten times what the drug cost him to make. He paid $200 for the radium and charged $2,000 for a small dose of the drug. The sick woman's husband, Heinz, went to everyone he knew to borrow the money, but he could only get together about $1,000, which is half of what it cost. He told the druggist that his wife was dying, and asked him to sell it cheaper or let him pay later. But the druggist said, "No, I discovered the drug and I'm going to make money from it." What should Heinz do now? [3]

After the dilemma is presented, the students will utilize Wallas's [4] process of preparation, incubation, illumination, and verification in order to decide the course of action Heinz should choose and why. The Heinz dilemma is an activity to facilitate the techniques of problem definition, brainstorming, and teamwork for the students. Their previous education has not given them the time and opportunity they need in order to see another possible solutions. By discussing this case, we assist students to accommodate multiple aspects of a situation in which they are able to see alternative solutions.

2.3 The importance of WWW learning environment

Most engineering students are quite capable of cooperation when they have a clear goal to work together. According to Csikszentmihalyi [5], a typical element of enjoying an activity is the presence of clear goal with immediate feedback. To accomplish this, it is necessary to create a learning environment that enhances the frequency and quality of group discussion. Therefore, we employ a web-base learning environment called *the creativity activity board* as the basis to deal with students' difficulties that emerge during problem solving. Due to their lack of experience and confidence in project design, the purposes of the creativity activity board are:

(1) To encourage students to seek help from teachers as well as from peers and therefore examine their problems from various perspectives.
(2) To emphasize the mutual goal of finishing the project when students are procrastinating, and
(3) To foster active interactions and immediate feedback among teachers and students.

The details for our WWW courseware are presented in the other paper by Hsiau et al. [6].

3. The strength of fostering creativity through projects

Traditional paper-and-pencil exam tests how much students had stored the knowledge, whereas the project design allows students to demonstrate the way they were integrating their understanding of the material and applying it to engineering contexts in a creative way [7]. Furthermore, projects could relate basic principles and concepts to real problems and to improve students' understanding, motivation and creativity [8]. We use projects as a showcase for student knowledge and creativity, the outcome of their work is intended to demonstrate:

(1) a mastery of basic CPS processes underlying the engineering method;
(2) a through understanding of the engineering design procedures and the ability to apply them with creativity;
(3) communication skills so that students can present their ideas clearly by verbal, written and graphic means.

Projects promote understanding of basic concepts, enabling proactive learning, and encouraging creativity. They stimulate an enjoyable realistic exercise while learning to perform duties as part of a professional team.

3.1 The rationale of project-based learning

Implementing a project is a way to encourage students to look deeply and laterally at individual topics and consider how they can be applied to real situation. They motivate students to confront both familiar and unfamiliar situations with confidence, providing a sense of achievement and satisfaction. The objectives of CPS activities in the engineering design are [9]:

(1) Showing the integration of engineering and problem solving skills,
(2) Developing more lateral thinking skills,
(3) Learning to better handle ambiguity, and
(4) Developing open-ended problem solving capabilities.

3.2 Procedures for creative project design

After lecturing the concepts and skills related to the application of problem-solving techniques to daily life, we use team project as a tool to foster creativity of engineering students. Project-based learning puts students in the position of prospective engineers to investigate phenomenon, develop hypothesis, collect and analyze data, verify and revise hypothesis, and draw conclusion [10].

To provide a basis for preliminary assessment, each team must submit Request for Proposal which includes the following eight elements where appropriate: (1) Outline of essential elements; (2) Objective; (3) Problem identification; (4) Methodology; (5) Tentative outcome; (6) Progress report; (7) Man power distribution; and (8) Funding requisition.

Each team member is expected to be aware of the specific skills of others in order to achieve effective and collaborative working relationships. More importantly, each member needs to take other people's views into account. Each project includes the following eight elements where appropriate: (1) Topic selecting; (2) Needs assessing; (3) Proposal requesting; (4) Information gathering; (5) Product drafting/designing; (6) Product pilot-testing; (7) Product fine-tuning; and (8) Report writing and presenting.

The following products are examples of creative projects made by students for the past two years.

(1) Umbrella dryer
(2) Electrical skater
(3) Automatically light-sensing lamp
(4) Automatic blackboard eraser
(5) Easy-to-dissemble roller blade
(6) Apple peeler with multiple blades
(7) Door lock via internet
(8) Horizontally-moved parking device for vehicle
(9) Innovative lock for bike

4. Results and discussions

The survey is conducted to discover the impact of the course and those aspects of learning experience and activity that most contribute to the cultivation of creativity for engineering students. In this study, we wish to answer three main questions:

(1) What are students' responses to the interdisciplinary teaching?
(2) Which aspects of the course do the students feel most rewarding and most frustrating?
(3) What are the reasons for students' preferences and difficulties?

Forty-six participants individually complete a questionnaire to reveal their learning preferences as well as difficulties in respect to interdisciplinary approach. Then, three of them volunteer to be interviewed afterwards.

4.1 Findings

Based on qualitative data from interviews, questionnaires, the most rewarding course content identified by the students is the creativity contest and project because they provide ample opportunities to solve real-life open-ended problems, rather than to deal with dichotomous textbook problems. Besides, the oral reports for explaining their team projects to the whole class are challenging but useful training that they hardly received from any other engineering courses.

Majority of participants support the idea of student-initiated, rather than faculty-initiated or industry-initiated, design project. Students enjoyed the feeling that they have learned as a result of their efforts. There are two types of positive experience found: enjoying the feeling that they have learned as a result of self-initiated, and enjoying the experiencing of interacting with peers and other experienced professionals. Their interactions with other experienced professionals had increased the knowledge base and skills of their own design. They believe that it stimulated their curiosity and ambition to success. Indeed, student-initiated topic selecting may be the driving force of developing the students' ability to find and to solve the problems by themselves. They learned to realize the constraints within which the prototypes are being implemented and to work effectively within these. Students indicated that the impact of such course-particularly the problem solving of their team project- extend beyond the enhancement of mechanical competence and the ability to function well as a team under pressure.

4.2 Reasons for problems experienced by students

The issues of students' learning difficulties are complex and dependent on a range of factors, including course organization and development, the subject or topic being taught, teaching style, and students' expectations [11]. Although students see the new learning experience as an opportunity to broaden their scope, some others claim that the challenge of finding a topic was beyond their ability to manage. In order to set the stage for project design, our data showed that it is crucial that team members to accommodate each other and to devote their personal commitment. It is clear from our interview that failure to do so did influence the students' motivation to finish the project.

The preliminary results of our survey also show that students might understand the theories and procedures they learned in the class, but unable to transfer to the design of the project. Most engineering students are quite capable of cooperating when they have a clear goal to work together. They are strong on active experimentation, and interested in practical uses for ideas and theories. Therefore, they would likely to create and work effectively if they see apparent use.

5. Conclusions

The members of collaborating teaching groups learn from one another. Each member is a specialist and become the tutor to the other members. More importantly, the effort of compromising one another on the process serves as a role model for their students to work cooperatively.

The evidence from our research indicates that students' problem solving processes were affected by their understanding of the rationale of interdisciplinary course development. The results of this study suggest significant concern for the students' anxiety created by the need to meet the special requirements of four individual teachers. It leads us to speculate whether the structure and sequence of the course development are appropriate to the students' level of capacities and motivation. This study also demonstrates that much creativity may be illustrated in extra-curricular activity and project design where students see the clear relevance and worth of intensive engagement in particular undertakings.

6. References

[1]. S. S.Hsiau, "A study of the course of open-ended, innovative and creative Design in mechanical engineering," final report of project: NSC 86-1512-S-008-001-EE, 1998.

[2]. S. J. Parnes, Sourcebook of Creative Problem Solving. Buffalo, NY: Creative Education Foundation, 1992.

[3]. L. E. Berk, The extracurriculum. In P. W. Jackson (Ed.), Handbook of research on curriculum, NY: Macmillan, 1991.

[4]. G. Wallas, The art of thought, New York: Harcourt Brace Jovanovich, 1926.

[5]. M. Csikszentmihalyi, "Creativity: flow and the psychology of discovery and invention," New York: HarperCollins, 1996.

[6]. S. S. Hsiau, J. C. Wu, T. L. Yeh and S. J. Tsai, "The web-based learning environment for creative design course," will be presented in 2000 International Conference on Engineering Education, Taipei, 2000.

[7]. C. Baillie and P. Walker, "Fostering creative thinking in student engineers," European Journal of Engineering Education, vol. 23, pp. 35-44, 1998.

[8]. Blicblau, A. S. and Steiner, J. M, "Fostering creativity through engineering projects," European Journal of Engineering Education, vol. 23, pp. 55-65, 1998.

[9]. C. A. Mullins, C J. Atman and L.J. Shuman, "Freshman engineers' performance when solving design problems," IEEE Transactions on Education, vol. 42, pp.281-286, 1999.

[10]. T. W. Chan, C. W. Hue, O. J. L. Tseng and C.Y Chou, "Spaces of network learning models," 2000, in preparation.

[11]. A. Pirrie, S. Hamilton and V. Wilson, "Multidisciplinary education: some issues and concerns," Educational Research, vol. 41, pp. 301-314, 1999.