Virtual, interdisciplinary and collaborative: Establishing student core competencies and instructional components in I-EDU innovative instructional project

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Educating Engineers for Global Competiveness:

INTRODUCTION

The rapid development of information technology propels knowledge explosion and the progress of human civilisation. Meanwhile, the ubiquitous computers, internet, and mobile devices have changed the means people absorb and create knowledge. Recently, cultivating creativity as an ability and building creative talent has become the focus for the higher education researchers in the engineering and design realm. Consequently, the current research centers on establishing and evaluating an innovative engineering instructional model (I-EDU Project) , which aims to ameliorate students' passive and conventional individual-focused learning model, as well as to enhance their essential competencies such as exploration, reflection, teamwork and creativity. I-EDU project consists of five projects, with 4 innovative course projects and an assessment study.

1 COURSE DESCRIPTIONS

The following are the descriptions of the 4 innovative courses in the I-EDU Project.

1.1. Sky Classroom

The purpose of sky classroom is to establish a cross-domain and cross-country learning environment, where students around the world can learn together smoothly without the restriction of time and space.

By adapting online cooperative pages, virtual discussion environment and tele-presence robots, students are able to form teams, to focus on the same topic and go for it through sky classroom. It is expected to find out more culture issues among international projects and future engineers can learn from it in advance. Four scenarios according to time and space are considered and their solutions are implemented. In an asynchronies and different places scenarios, students can utilize an online course system, Coursera, to self-study the basics of Engineering Graphics. As for synchronies and the same place, students are grouped in solid classroom and solve problem-based project by teamwork. About synchronies and different places scenarios, we plan to develop a virtual discussion environment so that students are represented by avatar in the virtual space and cooperatively work on the same drawing tool. For discussion purpose, we tend to develop P-Bot, a remote meeting robot with basic body language functions, such as expressing doubt, request speaking, viewing angle control, and so on.

1.2. Collaborative Game-based Learning

From a solid social cultural theoretical perspective, this project identified two design principles for game-based learning activities: perspective sharing and peer assessment. These principles will guide the development of innovative instructional strategies and mobile learning tools that support students to generate probability problems by applying various creative thinking strategies, such as addition, combination, transform, and extension. In order to assess change in students' understanding of probability, motivation, and creativity skills, we will collect and analyze data through pre- and post-questionnaire, open-ended questions, and probability problem solving activities. We will also conduct semi-structural interviews, participatory observation, and design portfolio to understand how students participate and benefit from the learning activities and tools. This project will recruit a group of approximately 50 students from a 16-week probability course in the department of electrical engineering in National Taiwan University each year. The results of this study will contribute to the development of theory and practice for game-based learning environment that supports engaging and effective learning experience in engineering education.

1.3. Designers for the future

This sub-project plans to develop a new course for development of engineering students' ability in solving unknown future problems through team collaboration and creativity. The courseware will be designed and developed jointly by instructors from fields of Civil Engineering, Architecture, Mechanical Engineering, and Future studies. The students in the class will be asked to address the sustainability and energy conservation issues in the NTU campus by creative team designs. The main tasks in the first year of this sub-project are course design and teaching materials development. The theory and application of future studies will also be introduced to all project participants to help development of

new future-oriented courseware. In the second year, the main tasks are the teaching and evaluation of the new course. The evaluation results will be compared with those of the “BIM Implementation Practice” course taught in the first year using a traditional approach. In the third year, based on the course evaluation results from the previous year, the new course will be further improved and taught the second time. In addition, the teaching materials will be modulated to facilitate the promotion of the developed course.

1.4. Cape Lab.

In view of experimental resources of each school or department having significant differences, this study proposes the idea of Cape Lab, and makes an attempt on sharing and integration of inter-institution experimental resources. With the cloud virtual interactive platform, Cape Lab fully meets the three teaching elements of the innovative educational platforms (i.EDU) which is virtual, crossborder and cooperative features. The control module of experimental resources is divided into two parts, an upper controller and lower controllers. The lower controllers have two functions, sensing and actuating. The upper controller can communicate with the lower controllers, connect to a wireless network, retrieve and transfer image information by using a control board like Raspberry Pi. In this study, we employ various types of plant factory built at NTU as an example to test the platform of Cape Lab according to the structure of lower and upper controllers. Cape Lab achieves sharing and integration of experimental resources through the clouds and mobile devices. Students can organise cross-school cooperation teams to share experimental resources, exchange viewpoints, broaden their horizons and effectively stimulate imagination and creativity through the Cape Lab mechanism.

2. STUDENT CORE COMPETENCEIES AND INSTRUCTIONAL COMPONENTS

Through literature review, interviews and focus group, the researcher has been able to construct five core competencies and three teaching components as a common axis to establish a suitable teaching model among the 4 innovative courses within the I-EDU project.

2.1. Three teaching components

2.1.1 Virtuality

Virtuality in the innovation teaching project refers to the use of computing virtual environment in the teaching process, which allows users to move freely and express themselves, as it is in the real world.

In addition, in the interactive virtual environment, because of the process of the interaction and the frequent communication among the participants, the multicultural experience helps bring together innovative ideas and innovations [12]. The virtual environment helps the participants to conceptualize and simulate the considerable cost of manpower and resources in need in reality, highly increasing the possibilities in the plan-making process before actually taking actions. Compared to the traditional classroom, virtual environment can effectively enhance the sense of participation and promote a more active role-taking [12].

Thus, the virtual element of teaching in the current study provides students with a free interactive field, and it enhances the essential ability of teamwork cooperation and interdisciplinary communication by breaking off the limitations of time and space.

2.1.2. Interdisciplinarity

The nature of interdisciplinarity in this project refers to learning in addition to one's own field of study. The different degrees of interdisciplinarity can be derived from different areas of learning, culture, and national boundaries. In the course of each project-making process, the highest interdisciplinary element includes not only students from different subject backgrounds, but also participants from different campus, national and cultural backgrounds. The courses with lower degrees of the interdisciplinary element are represented by student participants from one single department or the same professional background.

We have learnt, based on previous studies, that the work field encompassed the element of interdisciplinarity can enhance the creativity of the participants. For example, Rhoten et al. (2009) points out, through the interdisciplinary curriculum design which combined students from different professional backgrounds and investigated their innovative scientific research performance, that the effectiveness of a successful interdisciplinary program design is not only constituted by students from a single area of expertise, but also by students with the interdisciplinary ability to deal with different ideas. Furthermore, in practice, Petre (2003) have summarised the research of interdisciplinary engineering team, project making and the original patented product, induces that the interdisciplinary team can indeed enhance creativity. And frequently, the thoughts of integrated innovation emerge from the boundaries of different areas. By "getting out of the box" and moderate team support and trust, the interdisciplinary work platform can generate higher creativity. The goal of the interdisciplinary cooperation is practice-oriented, in that students' ability of interdisciplinarity and creativity can be enhanced by actual participation in problem-solving activities.

2.1.3. Collaboration

The element of collaboration in the current innovative engineering teaching project refers to the process of the project completion in which students must rely on the nature of teamwork and learning together. The higher degree of the collaboration in the teaching design is represented by the cooperation with and task completion by students coming from various countries and cultures. Next, the lower degree of collaboration can be represented by cooperation among different schools or departments as well as group work within a single class. Integrating the advantages of collaborative learning summarized by previous studies into this project, the current study of innovative engineering teaching aims to change the traditional approach to learning in Taiwan, which prioritises repetitive, mechanical practicing and solo effort or competing rather than cooperating. The project, instead, incorporates and emphasises the mind-oriented teaching/learning approach where observation, reflection, collaboration, communication and the enhancement of imagination and creativity are of importance.

2.2 Five core competencies

Among the individual's core competencies, five of which have been summarised in many empirical studies as showing high relevance to the creativity cultivation, these include observation, reflection, imagination, teamwork and interdisciplinary communication.

2.2.1. The ability of observation

Observation can be considered as a perceptive activity, a capacity of empathy and understanding. It can be further divided into full-scale observation, target observation, affective experiencing ability and information observation skill: (1) full-scale observation means one can use a variety of sensors to observe, take the individuality and integrity into account, observe repeatedly, improve the effectiveness and speed of observation, and understand the relationship between observation and perception; (2) target observation indicates one can observe for the needs of a specific problem, apply methods of observation, calibrate the observation plan, apply the observation procedures and discover and analyse potential problems during the observation process; (3) affective experiencing ability means that one can observe from the others' standpoint, attach importance to each other's feelings and ideas and empathize and understand each other's feelings and perspectives; (4) information observation skill refers to the use of multiple types of records to observe, the production of complete and timely records, the ability to summarise and organise the gathered information, the ability to carry out imagination and

memory transfer after gaining an affective understanding and the ability to regularly analyse the observed information through the use of conception and the background knowledge.

In the innovative engineering teaching design, individuals and teams should equip themselves with the ability of an acute and effective observation to achieve mission objectives. In the context of interdisciplinary collaboration, participants must continue to examine the process of trying, observing, adjusting and accepting other alternatives in order to achieve the goals. Thus, the elements of the innovative teaching method will serve as the motivation for the participants to enhance their ability of observation.

2.2.2. The ability of reflection

Reflection is a problem-solving ability transformed from doubts generated in thinking activity. It includes cognitive reflection, action reflection and experience reflection [10]: (1) cognitive reflection indicates that one is able to understand the process and reflect on the meaning, to understand the definitions of various reflection patterns and values, to respect new ideas and freedom of speech, never to blindly follow authority or outdated thought and speech and to reflect on and attach meanings to the source of past experience; (2) action reflection means one is able to use keen observation and broaden their minds to reflect, to analyse their own thoughts and feelings during the course of action, to reflect on the action, to give importance to the cognitive ability and increase its application, to apply diverse ways to record the reflection, to conduct affective reflection in the face of a complex experience, and to organise action in accordance with the previously encountered situations; (3) experience reflection refers to the ability to ask questions regularly, to integrate and evaluate prior experience, to simultaneously monitor their thinking, to think critically after the experience, to be self-aware and self-evaluated, to analyse the perceived thoughts, affection and action, to implement appropriate tools and methods, to reflect the analysis and inference, to eliminate confusion and solve problems, and to promote the practice.

2.2.3. The capacity for imagination

Imagination is the first step of all creative activities, so it should be vigorously studied and discussed. However, previous studies of human cognition have mainly focused on critical thinking, problem solving, and creative thinking. Little research has explored the essence and characteristics of imagination, let alone developed a concrete guiding model to cultivate it. Based on an extensive literature review, we

concluded that imagination is a mental process characterised by the following three key features: possibility, connectivity, and boundary crossing.

The imagining process is often cast as an innate endowment, flashes of inspiration, or even the illusions of a chaotic mind. Thus, it is concluded, it is impossible to cultivate. However, some scholars have claimed that design abilities, including imagination, can be articulated, and that educational programs can develop these abilities in students. The authors take the similar stand that, as with any human cognitive faculty, imagination can be developed, nurtured, and even trained. If we can unravel the features of the mental process of imagination and construct a procedure to facilitate such a process, then the cultivation of imagination becomes possible. Based on the above three characteristics of imagination, we propose an instructional model of imagination called IDEAL that is intended to enhance individuals' capacities to construct possibilities, connect perceptions and ideas, and to cross the boundary from the known to the unknown.

2.2.4. Teamwork

The meaning of teamwork can be, in fact, understood as cooperative learning which, in practice, dictates that one can effectively cooperate with individuals from different professional backgrounds. The members of the team may make prolonged efforts for the common objectives of the team because of a mutual relationship of helping each other. According to the definition of cooperative learning defined by Cuseo (1992), in this way of learning, the students are grouped according to different purposes, and different members of the group work together using different abilities to solve a problem or achieve their goals. At NTU iNSIGHT, the Centre of iNnovation and Synergy for Intelligent Home and living Technology, our learning process involves group members with different abilities helping and encouraging each other, and this is propelled by the members' positive interaction and knowledge exchange, rather than an antagonistic relationship. The dimension of teamwork contains (1) the ability to accept others' opinions and express oneself; (2) others-centred thinking ability; (3) the ability of carrying out professional coordination and negotiation of task distribution based on individual's characteristics; (4) the ability to review and adjust one's own perspectives in order to facilitate the target-oriented actions.

One of the objectives of designing the current innovative engineering curriculum, thus, is that of cultivating students' ability of communication and teamwork cooperation of accepting different points of view. This ability of teamwork cooperation helps ameliorate the previous competitive and/or individual style of learning, enhancing the effectiveness and quality of learning.

2.2.5. The ability of interdisciplinary communication

Interdisciplinary is an extension of the capability of handling cross-domain knowledge and communication, with a special emphasis on the contexts, social interactions and identification of different fields. According to our NTU iNSIGHT different dimensions of interdisciplinary communication include that: (1) the ability of interdisciplinary cognition points to the understanding of the definition of interdisciplinarity, the experience of interdisciplinarity, the ability of interdisciplinarity, the ability to learn through the interdisciplinary experience; (2) interdisciplinary sensitivity indicates that one can understand the importance of interdisciplinary communication, can apply the empathy of interdisciplinary communication , can focus on the interaction of interdisciplinary communication, can apply an open and active attitude to the interaction with those who participate in interdisciplinarity, and can apply communicative understanding to the interaction with those who participate in interdisciplinarity; (3) interdisciplinary understanding means that individuals are able to understand their own areas of expertise, to explain the definition of their own areas of expertise, to understand the influence of their own areas of expertise, to feel and observe the thoughts and feelings of those participating in interdisciplinarity, to accurately understand and judge by summarizing those participating in interdisciplinarity, to understand the professional cultures and cross-domain definitions, to observe the different standpoints of those participating in interdisciplinarity, can carry out the de-construction and re-construction of one's understanding in the light of experience of communication; (4) interdisciplinary application means that individuals can understand the effective communication strategies, can apply them to the interaction with those participating in interdisciplinarity, can express ideas at an appropriate time in the communication, can contribute in the interactive learning, can carry out rational and dialectical thinking in the communication, and can carry out teamwork after the communication skills have been applied.

Through communication and interaction, the ability of interdisciplinary cooperative communication fostered in the current innovative curriculum will lead different areas of expertise to overlapping, thus triggering the type of creative thinking that is previously unseen [3][4]. These ideas, escaped the existing frameworks, continue to be explored and utilised in the margins of various fields [4], and the learner's interdisciplinary communication skills and creativity can be simultaneously improved.

Concluding remarks: Overall, although the instructional themes and methods of each course in the innovative engineering project may differ, all of the teaching/curriculum designs are inextricably linked to the three major teaching components - virtuality, interdisciplinarity and collaboration. Through these essential instructional components, these courses aimed to foster students' five core competencies, including: observation, reflection, imagination, teamwork and interdisciplinary communication.

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