Developing an Engineering Course for Fostering Future-Oriented Interdisciplinary Team Design Skills

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Abstract: The rapid advancement of technology and changes in society in recent decades have made future engineering challenges harder to predict than ever. On the other hand, some elements crucial to cultivating problem-solving abilities targeting future issues can be readily identified: teamwork, innovation across multiple disciplines, future-oriented thinking, and creativity. Therefore, it is necessary to help civil engineering students develop these abilities. This paper reports an ongoing effort in the Department of Civil Engineering at National Taiwan University (NTU) on developing a course that intends to foster future-oriented team design power among students with a variety of expertise. Professors and experts from the fields of civil engineering, architecture, mechanical engineering, futures studies, and education are invited to co-teach and help develop the course contents. A student-centered, project-based approach is employed for students to learn in teams, with a team project theme of how to make the NTU campus more sustainable through Building Information Modeling-enabled design.

Keywords: Interdisciplinary Course Development, Futures Thinking, Engineering Education.

Introduction

The rapid advancement of technology and changes in society in recent decades have made it crucial for university education to enhance future-oriented thinking in order to help students adapt to a complex and diverse world. Future-oriented thinking is especially vital to engineering students and specialists because their designs must meet the demands of society in the future. However, the educational system in Taiwan mainly uses lectures as a teaching method in an instructor-centered and passive learning way, a method that does not emphasize training to imagine the future world. We contend that we must let students reflect on social issues and blind spots through long-term thinking towards the future and empower them to create alternative futures for themselves and for society. That is, the objective of future-oriented thinking in education is not merely to assist students to “future-proof” but also to help them actively construct their preferred futures (Facer 2011).

Engineering is a highly collaborative process (Bucciarelli 1996). Today’s complex engineering systems require the collaborative effort of engineers and non-engineers across multiple fields (Sheppard *et al.* 2008). It is necessary for teachers to create a learning environment for students to team up with different professional fields and to learn to communicate actively and positively with each other. To respond to these challenges, the Department of Civil Engineering of the National Taiwan University has recently made some curricular changes, creating a series of design project-based courses by integrating original and new programs. Cornerstone courses, aimed at fresh students before they start to learn professional civil knowledge, include imagination training and hands on practice. Optional keystone courses combining theory with pragmatic operations are offered to sophomore students. Examples of such courses include the design and construction of functional prototypes that exploit principles of structural and fluid mechanics. Finally, junior and senior students can take optional capstone courses, focusing on developing solutions to realistic engineering design problems (Capart *et al.* 2013).

The engineering course for fostering future-oriented interdisciplinary team design ability is designed to be a capstone course. This course is included in the undergraduate curriculum for university students, but graduate students also can take the course through a registration process, and even industry insiders can participate in specific modules of interest to them by sitting-in on this class. This research will be executed for three years. Teaching materials and teaching plans will be cultivated and amended back and forth through three instruction times, and the course effectiveness will be evaluated and refined by questionnaire and interview results from teachers and students. It is hoped that this course will be used as an example in the development of general teaching and learning principles, and that the resultant teaching and learning model could be applied to every department to tie previous and subsequent courses together into a series of interdisciplinary curricula.

Course Goals

One issue necessary to conquer and resolve in this course for the society of the future is the proposal of innovative design learning. Professors with different expertise are gathered and are invited to teach and help develop the course content. Students are divided into several groups by distinct departments or specialties and practice on a real case to learn and design creatively.

Three targets were designed in the teaching plans for this course:

Interdisciplinarity

Interdisciplinarity is a key feature of the design of this course. Teachers play the role of manager to arrange the course content. Since these lecturers are all from different departments, they must comprehend the relationship among their occupational domains before the course begins, and design a learning environment based on the learning situation of their targeted students. Furthermore, in order to help students to understand different fields, a range of necessary interdisciplinary skills is included. Thus, students can utilize their specialized skills well through cooperation with team members.

Collaboration

The ability to work and function as a team is a valuable skill for students to possess. They are distributed into heterogeneous group to achieve learning goals and finish learning missions together. They learn to trust, communicate, and interact with team members.

Virtuality

We bring imagination into real life by using virtual technology. By employing parameterized simulation functions with computer software in teaching, we can create realistic, future-appropriate scenarios. It is possible for students to simulate a wide range of circumstances in this virtual reality. Furthermore, they are able to modify future scenarios in the virtual space by comparing differences from the simulation results. Enabled by this visualization system, students are trained to have the ability to think independently, which will help them to make the right judgments and cultivate the ability to solve problems.

Students are encouraged to cultivate five core capabilities in this course using future-oriented thinking methods.

Interdisciplinary Communication

Communication among all the professors and students from areas of diverse expertise is the keystone of the current course. Lecturers are asked to help to develop course content for those who are unfamiliar with it. Furthermore, students are required to collaborate with their peers through this course. Both the lecturers and students could hence become familiar with each other and improve their communication skills.

Teamwork

Teamwork is one of the fundamental values of futurology. Future society should be framed by people working together, thus the ability to link and interact with each other will be very important. Therefore, we emphasize the value of teamwork and communication in the course design.

Imagination

Imagination is like a blueprint for the future. By exploiting a diverse array of futurology methods, the course assists students to sketch the future. Hence, they will not just stop at the imagination stage, and their capability to actually change the world will grow.

Observation

Students can find a specific role in society for themselves via several activities and hands-on practices, which focus on surveying the past, present, and future to observe society.

Reflection

Future thinking is a process of reflection. Differing from neutrality, future thinking enables people to implement certain values or test hypotheses of human beings from the past and present by extending the time scale and widening the point of view. Therefore, we can reshape the image of the future to fit contemporary visions.

Course Design and Implementation

The Technology and Application of BIM (Building Information Modeling) course was developed to enhance students' basic BIM knowledge and the skills applied in BIM for engineering issues for sophomore and graduate students at the Department of Civil Engineering of National Taiwan University since 2011. Furthermore, the BIM Implementation Practice course covering the practical design and analysis of a real, new building case was run at National Taiwan University campus in spring 2013.

BIM is a rapidly developing new technique in the architecture, civil, and construction fields. Key success factors of BIM implementation for engineering projects are interdisciplinarity, collaboration, and virtuality.

BIM uses a digital model to build, manage, and apply virtual construction for better control and integration before the actual execution of engineering projects. Regardless of what types of engineering works are examined, different staff and departments are required to cooperate across dissimilar engineering stages. The owner, designer, construction department, administrator, and supplier join the projects together and invest their efforts in distinct stages. Thus, communication and co-ordination are indispensable, an aspect that matches the teaching philosophy of this course.

In view of the above, we redesigned the BIM Implementation Practice course in spring 2014 to foster students' futures competencies, with "a sustainable NTU campus in 2030" as the center of all course activities. The course is integral in reinforcing every student's professional specialty and pushing ahead with team cooperation. The course took the NTU CSIE building as a case for innovation and design with BIM simulation and analysis methods, along with emphasizing energy conservation and water saving to improve existing buildings on campus and the environment in order to carry out the vision of sustainable campus in future.

This class was held for a total of 18 weeks on Monday nights and Wednesday afternoons in this semester, and one of the classes will be divided into two associated workshops on two designated weekends (table 1).

Table 1. The Content of the BIM Implementation Practice Course

Instructional strategies and methods	Percentage
Lecture	19%
Student Team Learning	12%
Workshop	12%
In-class Discussion	7%
Guest Speakers	19%
Final project	31%

Lecture

The contents of lectures were focused on interdisciplinarity. Since the course was held by the Department of Civil Engineering, it was expected that the backgrounds of attendants will generally be limited to the College of Engineering. Besides, considering that interdisciplinary communication is necessary for the working scenarios of civil engineers, the contents were designed specifically for those in the Architecture Department, Civil Engineering Department, and Mechanical Engineering Department. The content consisted of Building Information Model (BIM) technology, which is rapidly gaining popularity in the field of civil engineering, participatory design in architecture and urban planning, energy-saving performance measurement and verification methods for air conditioning. Before the execution of the course, all the teachers and teaching assistants were trained in future-oriented thinking by means of a workshop. We aimed to help students to comprehend the technical terms among different fields, and encourage communication and cooperation between team members.

Student Team Learning

After every lecture, students received certain related literature to study and discuss with the group. After discussing the literature, they collected other literature comprising different themes to report to the teacher and other group members.

Workshop

Students were asked to participate in a two-day workshop for future-oriented thinking. The theme of this workshop was the campus of the National Taiwan University in 2030. Using six pillars in futures thinking (i.e. mapping, anticipating, timing, deepening, creating alternatives, and transforming futures) to make trainees engage in future-oriented thinking, they discussed and envisioned university life in the future as engineering technology becomes more advanced, simultaneously reflecting changes in university education. They were also empowered to create futures based on their imagination, and apply the basic tools of futures thinking by means of hands-on practice (figure 1).

Figure 1. Presentation and Discussion at the Futures Thinking Workshop

In-class Discussion

We revised a futures triangle method and CLA (Causal Layered Analysis) in a workshop that made students practice these methods by teams. The futures triangle method employs an interaction using the pull of the future, push of the present, and weight of history to build a plausible future. CLA has four layers to resolve and deepen futures. The first layer is litany, the official unquestioned view of reality. The second level is the social causation level, the systemic perspective. The data of the litany is explained and questioned at the second level. The third level is the discourse/worldview. The deeper, unconsciously held ideological worldviews and discursive assumptions are unpacked at this level. The fourth level is the myth/metaphor, the unconscious emotive dimensions of the issue (figure 2). The challenge is to conduct research that moves up and down these layers of analysis and thus is inclusive of different forms of knowledge.

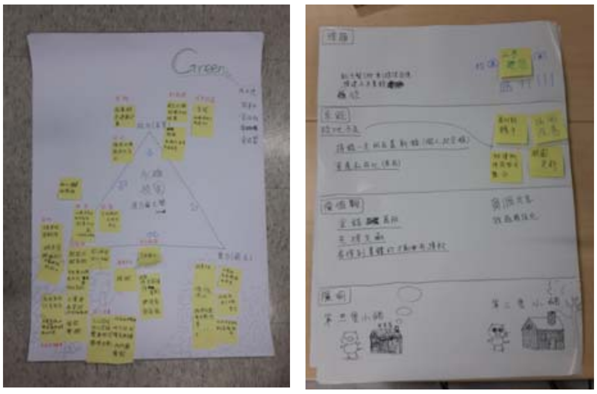

Figure 2. Futures Triangle Method and CLA for the NTU Campus

Guest Speaker

During the final project, we invited experts to share their experiences of energy conservation and water saving a total of seven times. After visiting an energy saving guidance group and campus planning group in NTU, students became able to comprehend the campus building principles of comprehensive planning, land development, and architectural programming with regard to policies and the current situation (figure 3). Depending on the sustainability issue in question, we had speeches from industry experts and architects with EEWH (Ecology, Energy Saving, Water Reduction, and Health) and LEED (Leadership in Energy and Environmental Design) practical experience, and researchers engaged in related energy and water research. Students could then apply relevant technologies and trends to develop imaginative designs in the final project.

Figure 3. Visiting an Energy Saving Guidance Group and Campus Planning Group in NTU

Final Project

For the final project, the requirements were as follows:

1. Imagination of the Future: Using the method of future-oriented thinking, students should discuss and picture their vision for the possible future sustainable campus, and clarify the demands for energy and water resources for the sustainable campus. In addition, students should also complete the following tasks:
   - Use the futures triangle to picture the possible future of the sustainable campus.
   - Use Casual Layered Analysis to pinpoint possible trends and issues for the future, and think deductively what future innovative architecture would be like.
   - Make proposals for achievable main policies and milestones accordingly.
2. Assessment and renovation project: Defining the unavoidable issues for the 2030 sustainable campus project using the case above. Energy and water saving issues should be included but other possible topics should not be excluded. A renovation project should be proposed accordingly. Besides, an assessment of the current situation is also needed. The items assessed should include the condition of the construction site, the existing building, the users, and their activities around the area. Green Building assessments such as LEED or EEWH should also be referred to for energy and water saving considerations at the time. Finally, a renovation project should be proposed according to the assessment above. The proposal should include the current situation, issues to be addressed, and possible solutions for improvement.
3. Design proposal: Using the same case to propose solid renovation ideas for energy and water saving, BIM technology should be used to simulate and analyze efficiency after the renovation.

Closure

All the lessons of the first year have been conducted. There were ten students in the first class. There was only one senior undergraduate student in the class, and the remainders were graduate students, including two doctoral students. In terms of their disciplines, one student was an architecture major and the others were civil engineering majors. Among those students from the Civil Engineering Department, one was from the Structural Engineering Division, one was from the Construction Engineering, and Management Division, and the rest were from the Computer-Aided Engineering Division. Because the course is offered by the Civil Engineering Department, it is difficult to attract students from other departments, and the course promotion was obviously insufficient. Furthermore, the name of the course, "BIM Implementation Practice," gives the impression that it only focuses on a specific technology (i.e., BIM) and fails to demonstrate the important aim of interdisciplinary cooperation. These are considered the reasons why the course did not attract more students from other departments.

In order to improve the heterogeneous cooperation of the students in the groups, we used the results of the Kolb's Learning Style survey to understand which learning methods the students applied most in their learning. Accordingly, we can divide the students into groups according to different departments, specialties, and learning styles. As for the training for future thinking, we used a two-day workshop and arranged teaching activities that allowed groups to discuss the issues involved in the project. We interviewed the students mid-term and at the end of the term to answer the following questions: Are the course arrangements useful for students to develop the five core abilities? What should be the chronological order of the five abilities? How can students get inspired through these training activities? We also had discussions with the teachers to figure out some issues: How can interdisciplinary results of learning methods be evaluated from the entire design of the curriculum? What level of interdisciplinary understanding should the students achieve in order to cooperate with people in other fields? How can teachers help students to develop their abilities in cross-boundary thinking and resolve problems through improving the curriculum?

In order to increase heterogeneity of the future course, the three professors are to offer a new course following the model of this one in the second year of this research. They will continue to co-teach the course but, in order to attract a variety of clusters of students, will offer a course in their individual departments (civil engineering, architecture, and futures studies). Teaching activities from the three courses are to be carried out together at the same time and in the same place. In addition, a new course title friendlier to students outside civil engineering will be utilized. Hopefully, in this way, we will attract a wider variety of students, even those from the fields of psychology, humanities, etc. to enrich the learning experiences of the students. In addition, we will reorganize and enhance the teaching elements developed in the first year and classify further the interrelationships among the five core abilities through teaching. Furthermore, we hope to establish the general principles of teaching and learning so that the other teachers can easily adopt these principles in their teaching and in the development of similar courses.

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