Pedagogical Learning from a Future-Oriented Interdisciplinary Design Course

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Abstract: This paper analyzes the experiences of students in an interdisciplinary, problem-based design course that aimed to enhance the students' capacities in interdisciplinary teamwork, collaboration, problem solving, futures thinking, innovative design, and emerging technology. Students were mainly from three different engineering programs at National Taiwan University: civil engineering, building and planning, and mechanical engineering. In this course, students were asked to assume one role from three professional roles: architects and planners, civil engineers, and mechanical engineers. They were then grouped into interdisciplinary teams and given an assignment to revitalize and reuse one apartment building in an old neighborhood, which has been designated for urban renewal in the near future. Using this real world issue, the course was devised to train students in solving real-world problems and understanding real-world communities. Applying futures thinking in the design process helped the students foresee the needs of future societies and anticipate future problems, which are often ill-structured, ambiguous, and have multiple open solutions. In this paper, the curricular and pedagogical designs of this course are described and feedback from students is analyzed and presented, with the intention of helping teachers develop better interdisciplinary design courses.

Keywords: problem-based learning, interdisciplinary design, future thinking, engineering education.

Introduction

With globalization, the problems of the future cannot be resolved by experts from a single area of knowledge. With regard to the overall scale of the demand for various skills in 2020, the majority of jobs, across all industries, are expected to require complex problem-solving as one of their core skills (World Economic Forum, 2016). In recent years, internationally, the focus of engineering education curriculum reform has shifted from emphasizing knowledge transfer and data analysis to applying interdisciplinary learning to real world problems. Bringing the liberal arts to engineering education helps students expansively and imaginatively devise innovative solutions to resolve novel or ill-defined questions for a real and complex world (Bordoloi & Winebrake, 2015). Futures thinking can lead students to imagine futures beyond the superficial view of the public (Groff, 2014). Using futures thinking in education helps students to develop informed insights about shifts of values, focuses, and attitudes and to realize that most negative attitudes towards the future are based on misconceptions (Slaughter, 2008). Moreover, futures thinking provides multiple orientations or methods by which to explore possible transformations in different areas and the layers of future societies. It offers a variety of alternatives, elucidates possibilities, and evaluates the possible consequences of different actions (OECD, 2009). Therefore, the interdisciplinary course developed in the present research is based on the learning characteristics of engineering students, and students are required to resolve real-world problems in class. Integrating futures thinking into teaching strategies can help decrease the difficulties and obstacles students face while solving interdisciplinary problems, and also cultivate the ability of students to think in diverse ways.

Background

This research is the final year of an ongoing three-year project funded by the Ministry of Science and Technology, Executive Yuan in Taiwan to encourage interdisciplinary courses in engineering programs at the university level. The research team is composed of teachers from the Department of Civil Engineering, the Graduate Institute of Building and Planning, and the Department of Mechanical Engineering at National Taiwan University (NTU), and from the Graduate Institute of Futures Studies at Tamkang University who, together, offered an interdisciplinary course. In the second year of the course, the Nanjichang (Southern Airport) Housing Community was chosen to be the case study. The buildings of the community were constructed more than fifty years ago and are in poor condition, thus an urban regeneration

project is desperately needed. In addition, several common social issues in Taiwan, such as an aging population, underprivileged families, low birth rates, and new immigrants, are also pervasive in the community. First, the interdisciplinary team conducted interviews with community residents and established investigations in the community. Then, following the course discussions, students came up with three items for reform and identified their corresponding solutions. These three items were: space planning, night market relocation, and immigrant settlement.

Some adjustments were made in terms of course arrangement and activities this year, based on the student feedback from the previous year (Chen et al. 2015). These include:

- Forming "professional groups" among students: students were assigned professional roles based on their training.
- Conducting a pre-course workshop: this was a warm-up opportunity to experience the community environment and form a disciplinary team with new classmates.
- The course was open to students from three departments in engineering at NTU and no longer involved students from Futures Studies at Tamkang University.
- The project theme was pared down to feature only engineering-related issues, as opposed to the renewal and reconstruction of a tenement.

Course Design and Implementation

The course combined three courses from NTU: the Civil Engineering Capstone Challenge course with three credits in the Department of Civil Engineering, the Practice of Environment Planning and Design (I) course with six credits in the Graduate Institute of Building and Planning, and the Energy Conservation Design in Green Buildings course with three credits in the Department of Mechanical Engineering, and was held on Friday afternoons in the spring semester of 2016. Some extra courses on professional knowledge were held on Monday evenings for Civil Engineering students and Tuesday afternoons for Building and Planning students. A teacher and teaching assistant from the Graduate Institute of Futures Studies at Tamkang University provided learning activities on futures thinking. Students needed to cooperate and interact with people outside the classroom by conducting interviews with community residents as well as community investigations.

The final project of this course was an old building revitalization plan for the Nanjichang Housing community. Each team picked an existing building to redesign and proposed a retrofit plan with future visions after considering urban regeneration policies and the future of community development.

Course Objectives

In the course, students were expected to gain skills such as: interdisciplinary teamwork, problem solving, futures thinking, creative thinking, and emerging technologies skills. Some of the course goals were to integrate each teacher's teaching ideas and evaluate the effects on student learning:

- Students could form learning teams and attain the knowledge and skills of other domains through interdisciplinary learning and cooperation.
- Students could cultivate creative and innovative thinking, and strategize and plan by cooperating with different professional team members in their interdisciplinary team.
- Students could make good use of emerging technologies to resolve the problems of real communities and societies.
- Students could contribute to engineering innovation and forward planning, and lead residents to describe their community vision when participating in community activities by using futures thinking.

Course Process

The course consisted of a pre-course workshop, community recognition, site selection, building planning, and design proposal (See Figure 1) with different learning goals and outcomes. Various teaching methods such as field visits, group discussions, hands-on activities, case studies, after-class assignments, guest speakers, and group discussions, were used to aid student learning (Figure 1). Teachers and judgment committees evaluated interdisciplinary teamwork, problem solving, futures thinking, creative thinking and the emerging technology skills in the students' learning reports on a five grading scale (5-excellent, 4-Good, 3-Average, 2-Fair and 1-poor).

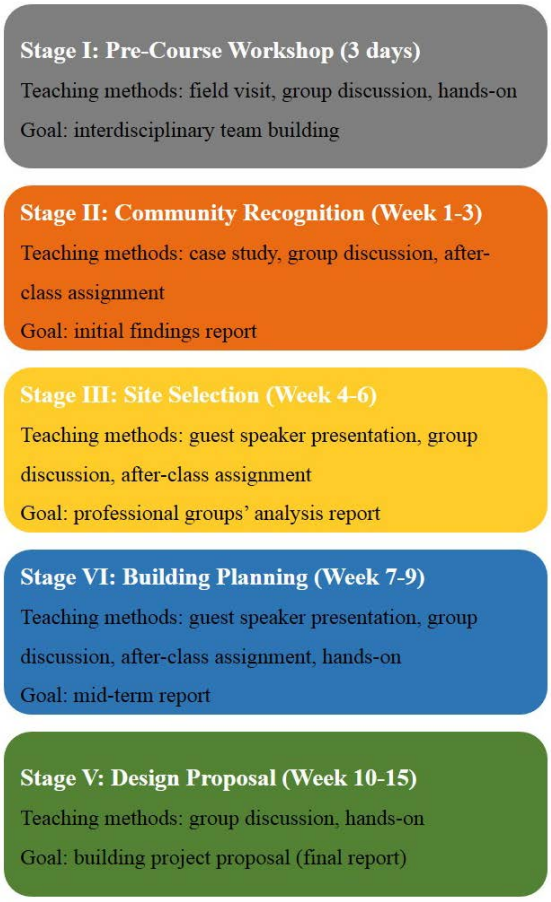

Figure 1. Five Stage Course Execution Process

Pre-Course workshop

A three-day workshop was held in the Nanjichang Housing community for students to explore the environment before the course began. The main features of the workshop were: futures thinking, community observation and design, and prototyping. The workshop was an opportunity for students to break the ice and identify the specialties of their fellow students.

The futures thinking workshop adopted the basic framework of the "Six Pillars of Futures Studies," which includes various approaches to envision the future such as mapping the future, anticipating the future, timing the future, deepening the future, creating alternatives, and transforming the future (Figure 2 & 3). In the community observation activity students were required to record or draft what they had observed after visiting the neighborhood magistrate, inhabitants, and investigating the space. The design workshop required students to provide a future-oriented community redesign plan that was based on the results of the futures thinking workshop and community observation.

Professional Group and Learning Group

Students were grouped into professional groups according to their learning background to provide adequate design solutions for structural retrofits, urban renewal, and energy saving. In addition, they needed to form learning groups by themselves to accomplish their final projects. At different stages in the course they exchanged the roles of consultants and designers to produce their reports (See Figure 4).

Responsibilities of the Professional groups:

- The Architect and Planner group: in charge of comprehensive planning and design; members were mainly from the Institute of Building and Planning.
- The Civil Engineer group: in charge of building's structural design, energy conservation, and financial planning; members were mainly from the Department of Civil Engineering.
- The Mechanical Engineer group: in charge of planning and designing fire protection and air conditioning; members were mainly from the Department of Mechanical Engineering.

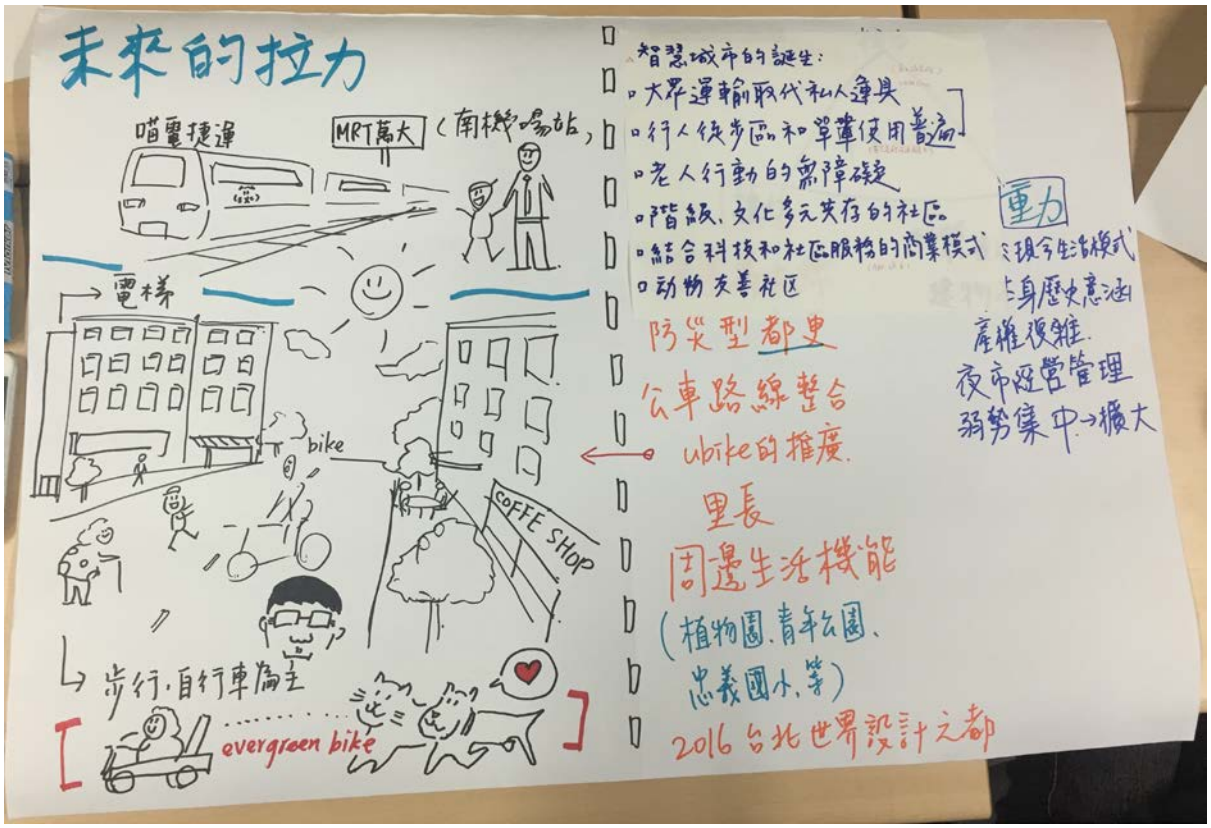

Figure 2. The futures triangle method uses the pull of the future, push of the present, and weight of history to build a plausible future for the Nanjichang Housing community.

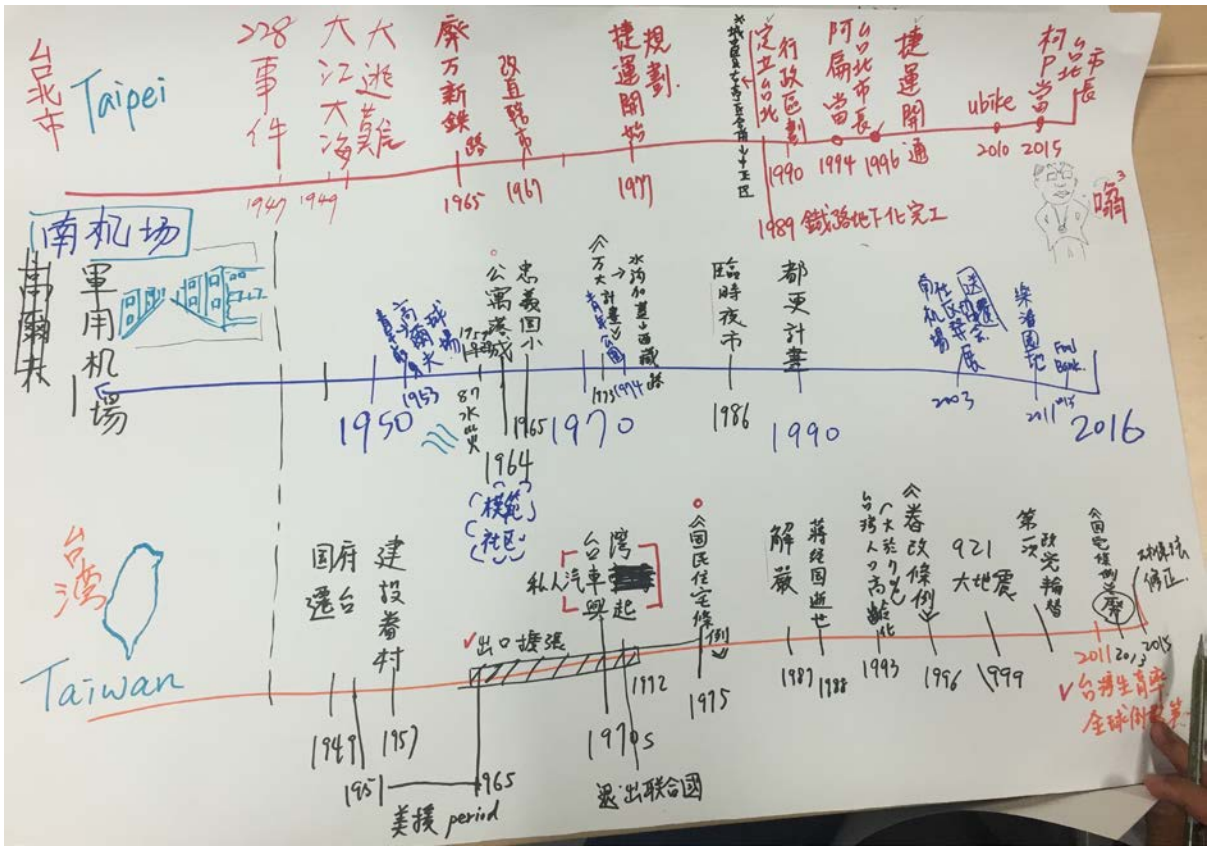

Figure 3. The timeline presents a brief overview of events in Taiwan, Taipei, and in the Nanjichang Housing Community.

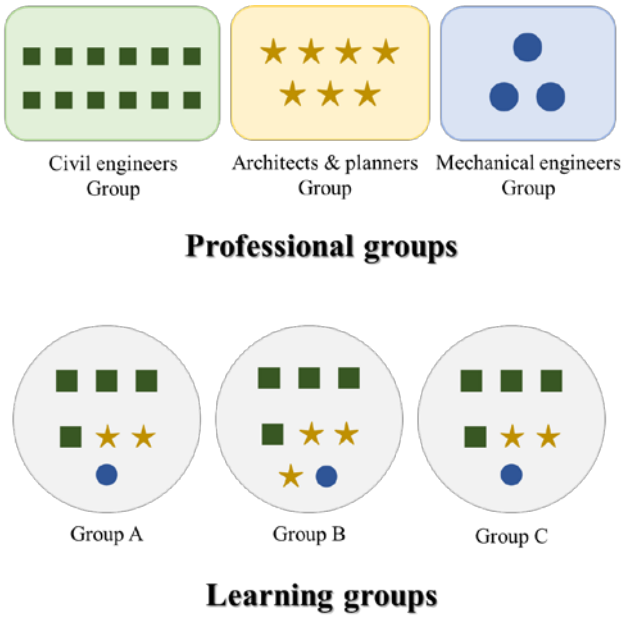

Figure 4. Member Distributions for the Professional Group and the Learning Group

Outcomes

There were twenty-two students in the course: seven females and fifteen males. Among these students, ten were from the Department of Civil Engineering, one was from the Department of Atmospheric Sciences, and one was from the Department of Bioenvironmental Systems Engineering; all were university undergraduates. In addition, there were seven students from the Graduate Institute of Building and Planning, and three from the Department of Mechanical Engineering; all were graduate students.

Based on a preliminary analysis of the interview data collected during the course, we obtained the following major findings.

Responses of Students

The answers of students to the interview questions are provided in Table 1.

- **Learning expectations**: Half of the students mentioned that they were very much looking forward to cooperating with students from the other fields and gaining professional knowledge from each of the programs. They thought that the interdisciplinary learning process was challenging, but might be interesting and spark the inclination to interact with different domains of knowledge. They were also looking forward to learning and exercising the skills of Building Information Modeling (BIM), structural reinforcement, urban renewal, and energy analysis in the final project.
- **Learning gains and difficulties**: Students commented that interdisciplinary communication was their greatest gain but also the hardest part of the course. As they needed to understand a variety of ideas, habitual words, and thinking methods in every group discussion, they had to put in extra time for learning. However, students' performances were affected by class participation, close-mindedness to suggestions, the discussion atmosphere, and insufficient abilities, all of which were obstacles for communicating with others.
- **Perceptions of course design**: Group discussions were arranged almost every week in this course, which helped students with creating design ideas. Some civil engineering students felt that they learned structural reinforcement rapidly and easily through the real cases. On the other hand, students felt that the professional grouping was malfunctioning and depriving them of the right to learn other fields of knowledge. Yet, they also mentioned that members of professional groups had more ideas and advice on their own domain than they themselves did. Some thought they had learned the skills of futures thinking, but still had difficulties in applying futures thinking in the final project.

Table 1. Interview Results Analysis

Interview Questions and Answers		**Numbers of Respondents**	
1. What were your reasons and expectations for taking the course?		22	
	Design proposal can be accepted by the government	4	18%
	Nanjichang Housing community	6	27%
	Structural reinforcement, urban renewal, and green building	11	50%
	Interdisciplinary cooperation	11	50%
	Hands-on project	8	36%
2. What did you gain in this course?		20	
	Futures thinking	6	30%
	Self-learning	1	5%
	Understanding space planning and urban renewal	4	20%
	Retrofitting design of building structure	5	25%
	Interdisciplinary communication	11	55%
	Breaking away from old thinking	4	20%
3. What difficulties did you encounter in this course?		17	
	Short working time	1	6%
	Division of work	3	18%
	Lack of prior knowledge	4	24%
	Different opinions from different teachers	1	6%
	Interdisciplinary communication	11	65%
4. What were the useful elements of the course design?		15	
	Professional grouping before learning groups	2	13%
	Pre-semester workshop	3	20%
	Extra courses	6	40%
	Interdisciplinary cooperation	6	40%
	Field work	1	7%
	Relevance of guest speakers to team projects	3	2%
5. What elements of the course design did not work?		14	
	Professional grouping	7	50%
	Difficulties in applying futures thinking	5	36%
	Excessive time spent on deliberation in earlier stages of the course	3	21%
	Irrelevance of guest speakers to team projects	4	29%

From the results, we identified the following issues with the new course design:

- Interdisciplinary communication: Students felt the differences between working alone and teamwork through interdisciplinary cooperation. They needed discussions to agree on particular subjects due to their different professional learning backgrounds. Sometimes difficulties in communication happened as a result of a lack of relevant background knowledge to be able to comprehend what others were saying. Without effective tools and proper communication methods this had a negative impact on the team's overall outcomes.
- Practical application of futures thinking skills: students only understood the meaning and importance of futures thinking after the learning activities. They knew futures thinking would help them envision the world with more long-term perspectives. However, there were issues in applying futures thinking to the project. Students gave up easily because of the unfamiliar operations and obstructions to their thinking processes. This caused students to think that, in general, futures thinking was useless.
- The function of guest speakers: students expected to have more interaction with guest speakers in relevant topics instead of simply listening to the speakers' lectures. They found that advice from the guest speakers could further benefit their projects more than just a lecture.

Reflections of Teachers

From the teachers' point of view, some elements of the course design could be better improved based on their experiences in this course.

- Teachers should come up with questions, develop dialogue skills in the students, and guide the discussions of the learning groups. However, redundant descriptions limit the creativity and imaginations of the students.
- Inconsistent course credits remained a problem for the course. However, students responded differently than in the previous year that the course was run. Harmonious team cooperation boosted course participation and student interest in learning.
- Students were confused about what were asked to do for the final projects when the demands contradicted current urban regeneration policies. Flexible topics will enable the students to follow policies instead of fighting against them. There will be a greater chance of success in the upcoming course if students could plan for the future using present-day standards and techniques.
- The number of students in each program depends on the topic of final project; it impacted active and negative behaviors in this course.

Conclusion

Different aspects of pedagogical learning were acquired during the course. The course design provided a fertile ground for interdisciplinary cooperation among teachers and students. Using cases from the "real world" helped students perceive the need for cooperation with those outside of their own professional background. Interdisciplinary communication was clearly the main attraction for the students but also required a lot more sophisticated curricular design than what was implemented. For instance, experiences from the previous year informed us that a complete mix-up of students' background in each group caused too much confusion for the students. We thus created "professional groups" to help strengthen knowledge in respective disciplines. This year, however, students felt that the professional groups were too much of a constraint to the choices in their roles.

We also narrowed the scope of the issue for students to study and confined the course work to engineering issues in this year's course. This apparently helped reduce student workload and enabled them to focus more on studying the issues at hand instead of investing too much energy on exploring the community. The trade-off, on the other hand, was a reduction of diversity in the issues chosen by students.

The incorporation of futures studies into the curriculum needed more work than we first anticipated. Students were able to understand and remember the ideas from futures thinking and even to apply them to the project with the teachers' guidance. Difficulties in application occurred when they needed to apply these ideas on their own for the final project. This issue requires a more meticulous teaching design to assist student learning.

Through their performance in class, students showed their skills in interdisciplinary teamwork, problem solving, and emerging technology, which could also be seen in the results of their projects and feedback at interviews. Next year, the course will be held in the Stanley Wang D-School@NTU to recruit pluralistic students who do not have the limitation of program regulation. The role of teachers will be to create a learning environment that encourages students to achieve their learning goals. Some issues with communication, design, and futures thinking will be incorporated sophisticatedly into teaching methods and materials. We anticipate that more participants from non-engineering fields can enlarge the scope of the project in the interdisciplinary design course.

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