Multidisciplinary capstone design experiences: reviewing through systemic approach for further development

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Abstract

At the University of Ulsan, we have implemented capstone design courses for engineering education through a decade. Recently the growing interest and need of multidisciplinary cooperation in the field of engineering urges us to develop a new approach to design and implement capstone design courses. We provided opportunities of collaboration and cooperation among our faculty, students, and even business and public participants through offering a new "multidisciplinary capstone design course". This presentation will address our experience in designing the working platform, recruiting procedures, administrative support, course implementation, and course result review through our first semester multidisciplinary capstone design course experiences. Systemic approach has been used to identify and analyze the important factors and relationships embedded in the course, so the result will be presented in systemic way.

Keywords: *Capstone design, Multidisciplinary education, Systemic approach.*

1. Background of the study

At the University of Ulsan's college of engineering, undergraduate students are able to participate in a project-based capstone design course in their third and final year. Each team of students taking capstone design course works on a different real-world problem and issue of engineering, advised in the process by a faculty member.

The purpose of capstone design course is providing comprehensive experience that helps students to acknowledge their strengths and weaknesses in their skill and knowledge to deal with real-world tasks. This experience could facilitate students' smooth transition from academia to profession. There are several specific goals for student learning in capstone design course

a) Integrating fundamental theory, knowledge, principles while students take part in the real engineering practice
b) Developing interpersonal skills such as teamwork, written and oral communication, leadership, and task management as core competencies for engineering professional
c) Learning business-related skills including proposing and evaluating work and doing cost effective work

In order to achieve the above goal, University of Ulsan offered capstone design course, previously named "creative engineering design". Recently, there are increasing interests about the multidisciplinary education not in the field of engineering education, but also in other areas such as social sciences, natural sciences, business administration, and even in K-12 education. As the level of complexity that we faced in our daily life and workplace is increasing, it become more important educational goal to raise graduate who has appropriate capability to deal with such problem and task in a collaborative manner. Consequently, there are needs of offering new types of capstone experience focusing on multidisciplinary collaboration in engineering education.

The purpose of this study is to introduce our multidisciplinary capstone course which was implemented in 2013 and elicit implications for program development in the future. In order to address the above issues, we reviewed previous discussions about capstone experience and multidisciplinary, and then we analysed students survey data about their multidisciplinary capstone experiences. Finally, we applied a systemic model (ADDIE) to review our current practices and to elicit implications.

2. Theoretical and practical review

2.1. Capstone design and engineering education

Capstone courses have been regarded as a higher venue for learning in that involving student in learning experiences that go beyond the restrictive boundaries of traditional curricula. [1] Through capstone experiences, students go through an extended process of inquiry in response to a complex question, problem, task, and challenge. Students are expected to demonstrate the ability of planning, assessing, and collecting appropriate information while they engage in critical analysis and decision-making to generate new meaning. As a result, learners are able to assimilate and apply knowledge while building much deeper level of understanding. In summary, capstone course experience can be designed to help learners in general [1]:

a) Understand the connection between curriculum and learning objectives
b) Reflect on what they have learned as a result of a program of study
c) Visualize the application of learned knowledge and skills to the workplace
d) Reflect on the issues involved in the transition into their next phase of education or professional career
e) Build life-long learning skills
f) Develop the capacities desired by their future employers

Capstone courses are fairly common in higher education. Especially, the adoption of accreditation system in engineering education (i.e., ABET, ABEEK), which emphasizes developing professional skills in engineering education, has accelerated the expansion of capstone course in colleges and universities. Typically the process of capstone course could be depicted as follows. Students would form groups of five to ten people, and each team would find a project client or their advisor, who could give a project idea, before semester started. When the semester begins, each group of students registers capstone class that is taught by their advisor or a group of advisors having similar project characteristics. For the first few weeks, the faculty member, client, and group would work to define a project. In the remainder of semester the group would do its work while they got continuous feedback and advice from their advisor. At the end of semester, the advisor, who oversee the entire process of capstone course, evaluate the outcomes and processes and assign each student's grade.

Providing capstone course has produced certain positive effects on student learning. For example, results from the National Survey of Student Engagement Report showed that capstone experiences increase overall student performance. Furthermore, data suggested that capstone course may offer all students an opportunity to succeed regardless of their previous level of achievement. [1] Students also report higher level of learning satisfaction compared to conventional theory-based engineering class. [2] [3]

However, several concerns or area for improvement has been reported. First, many capstone design courses are still insufficient in preparing engineering graduates for the changing and expanded needs in workplace, especially with regard to nontechnical skills [3]. Second, it is hard to find a structure or system to ensure constant implementation of the advising and grading which lead to high level of variability in project quality and student experience. [1] [3] Third, some students may experience stressful situation, because usually producing final product of capstone course requires more time than students initial expectation. Especially senior students, who have to prepare their graduation and job interview, reported the perceived burden of capstone experience. [2]

2.2. Multidisciplinarity and engineering education

Since the twentieth century, the dominant structure of education (from K12 to higher education) was the discipline based department and subject. [4] The Latin word 'disciplina', which is the root of current term 'discipline', means an educational setting and the instruction of disciples. In the late nineteenth century and early twentieth century, modernized school system adopted separate and segmented academic disciplines during its institutionalizing process. Klein argued that the process of knowledge production based on discipline could be characterized by two aspects. [4] The first feature is a functional differentiation that produces a distinct worldview or discourse such as isolated subject matter and objects, academic evidence, content, models, concepts and theories, methods and procedures, language and argument styles, ontologies and epistemologies. The second feature is a system of power that controls the nature of work in a specific domain, such as departmental unit of teaching and research, structure of profession, behavioral culture, employment and labor market, and economic value. Although conventional disciplines have the above common features, diverse technical distinction has been made. For example, researchers introduced a taxonomy of discipline type such as highly codified (math, natural science) versus less codified discipline (humanities, social science), and high paradigm fields (physics, chemistry) versus low paradigm fields (sociology, political sciences).

Then why the traditional structure of education based on discipline has been challenged recently? Researchers have been pointed out several factors and circumstances regarding the above question. [5] [6] First, the life span of knowledge has been incredibly reduced while new knowledge is explosively increasing. Especially, many new type of knowledge has been generated in the blurred area among disciplines that consequently leads the construction of novel disciplines such as cognitive science and human-computer interaction. Second, interdisciplinarity is a key factor in our contemporary life. We have faced very complex problems in our daily life that could hardly be solved by sole approach of a certain discipline. Increased demands for problem solving have fortified interest in collaboration and the ability to work with multiple sources of knowledge and diverse people with different perspectives and backgrounds. Third, knowledge and its related discipline is not a fixed concept but an evolving concept. Historical development of the disciplines shows us that the development of certain discipline demands new perspectives to provide innovations. This type of insights can come from other disciplines. Sometimes, biology needs mathematics at a certain stage of its development. Engineers seek to relationship with instructional designer. In this context, interdisciplinarity arises naturally among disciplinary expert. [6]

A number of definitions and terms for addressing how to link diverse subjects and disciplines have been used according to the fields and researchers. For instance, terms such as integrated, interdisciplinary, multidisciplinary, transdisciplinary, cross-disciplinary, meta-disciplinary has been used for indicating more than two subjects or disciplines are connected or restructured in the area of knowledge, research, instruction, and theory. [4] [5] [6]

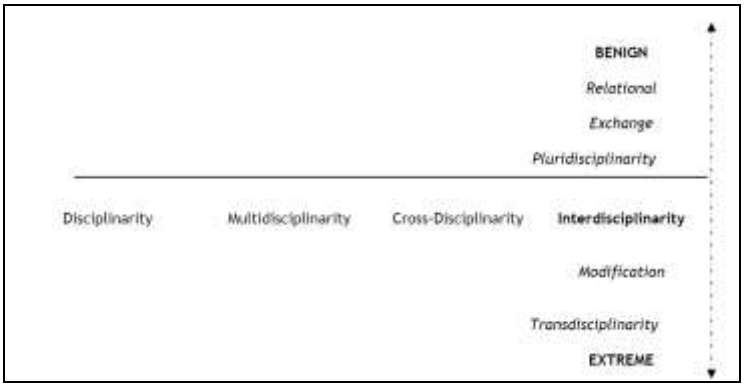

Figure 1. Various forms of disciplinarity (adopted from [6]).

Figure 1 shows an example of conceptual taxonomy about disciplinarity. The term 'disciplinarity' describes the traditional view. It has been used to describe academic disciplines as autonomous and discrete field of study which do not usually cooperate or collaborate with other areas. Multidisciplinarity admit that there are many discrete and autonomous disciplines. In the context of multidisciplinary, each of disciplines stands alone while some areas are co-existent with a number of disciplines. Cross-disciplinarity is another variation of disciplinarity. In cross-disciplinarity, an issue which is usually outside a field of study is examined with no cooperation from others in the area of study. This concept is focused on the use of foreign techniques and methods from those normally used to study the phenomenon under consideration. Lastly, interdisciplinarity has been described as a remedy to the negative effects of excessive specialization. As shown in the Figure 1, interdisciplinarity can be understood as a continuum from benign to radical. Benign sides of interdisciplinarity refers when two or more disciplines are contributing their particular disciplinary knowledge on a common subject (relational interdisciplinarity); exchanging critique and critical perspectives (exchange interdisciplinarity); or combining their expertise to jointly address an area of common concern (pluridisciplinarity). Moving to the other side of continuum, there is another variation of interdisciplinarity. Modification interdisciplinarity involved more that cooperation among disciplines. It needs that disciplines are changed/modified in some way by the association with other disciplines. Transdisciplinarity, which is at the extreme end, is a view of interdisciplinarity as involving the collapse of academic boundaries and the followed emergence of a new discipline.

3. Multidisciplinary Capstone Design: A case study

3.1. Course design and implementation

University of Ulsan has offered several types of capstone design course according to the scope and characteristics of project. Junior students take 'Capstone Design I (basic engineering design)' which offers student to topical seminar focusing on creative engineering problem solving through case study or group project on a relatively simple task. Senior students are participate in 'Capstone Design II (in-depth engineering design)' that provide more challenging and real engineering design tasks. In 2013, multidisciplinary capstone course was added in the previous capstone curriculum. All faculty members received email and electronic bulletin board notice regarding this newly developed capstone course. Faculty members were encouraged to suggest appropriate topics that could lead multidisciplinary cooperation. Faculty members proposed their initial ideas that represent their interests or industry partners' needs and then multidisciplinary capstone committee decided appropriate topics. Selected topics for multidisciplinary capstone design course were opened to all students so that students could choose specific course according to their own need and interest. Before semester starts, all faculty members who are participating multidisciplinary capstone course gathered to introduce each team's topics and way to project implementation. During the semester each team implemented their own project, and the university provided small amount of fund (about 1,000 us dollars) for developing final product of the project.
At the end of semester, a competition for capstone design courses including capstone I, capstone II, and multidisciplinary capstone was held for sharing learning experiences and final products of students. Table 1 shows the list of topics conducted by multidisciplinary capstone design teams. As show in Table 1, half of capstone teams included at least one of departments in the field of engineering while they jointly implement other disciplines such as humanities, social sciences, design and human ecology.

Table 1. List of multidisciplinary capstone design team in 2013.

Topic	Participating departments	students
- Public arts for "making beautiful community" project	- Oriental paintings, Western paintings	7
- UL souvenir development	- Humanities, Social sciences	4
- Cultural and historical expedition program in Ulsan for foreign visitors	- History & culture, English	6
- Designing athletic wear	- Human ecology, Natural sciences	7
- Tourism and marketing program for 'bangudae'	*- Design, Materials science & engineering*	17
- Developing intelligent vehicle seat	*- Materials science & engineering, Mechanical & automotive*	6

	engineering	
- Regenerative braking system for two-wheel electronic vehicle	*- Mechanical & automotive engineering, Electrical & electronic engineering*	5
- Developing instructional model for after school mathematics program taught in English	- English, Mathematics	12
- Entry-level UV lithography prototype manual development based on wafer type and PERL structure and PV Cell Production	*- Materials science & engineering, Chemistry*	6
- Intelligent vehicle control using sensing and vision	*- Mechanical & automotive engineering, Electrical & electronic engineering*	7
- Intelligent quadcopter control using Android mobile controller	*- Mechanical & automotive engineering, Electrical & electronic engineering*	7
- Mini beam project with analogue sensibility	*- Design, Naval architecture & ocean engineering*	6
- Four season tourism program in Gyeong-nam province	- English, Exercise & sports science	10
- Whale expedition program	- Biological science, English	8
- Cognitive development materials for senior citizen	*- Electrical & electronic engineering, Human ecology*	15
- Yoga wear for man and women	- Human ecology, Humanities, Social sciences	6
- Snapback design for sport activity	- Human ecology, Humanities, Social sciences	5
- Emergency brake system for unmanned vehicle	*- Mechanical & automotive engineering, Electrical & electronic engineering*	13
- TRIZ contents development with ICT	*- Mechanical & automotive engineering, Electrical & electronic engineering*	10
- Tutor development program for after school	- English, Mathematics	10

3.2. Student perception of multidisciplinary capstone experience

In order to explore students' perception about their learning experiences through newly offered multidisciplinary capstone design course, we implemented a survey at the end of semester. A survey included 16 items for assessing student perception about overall course satisfaction, course structure and contents, self-evaluation on their learning engagement and learning result, and university support. The survey, except the item number 7 and 8 applied only for the multidisciplinary capstone, was also administered to the students who took capstone II for comparison. As mentioned earlier, capstone II (in-depth engineering design) was provided by each department without interdisciplinary cooperation. Table 2 and Figure 2 show the mean of two group of student response to each survey item.

Table 2. Comparison of student survey response.

Sub areas	Question number	Items	Capstone II (n=204)	Multidisciplinary capstone (n=73)
Course satisfaction	1	Overall satisfaction	4.23	4.23
	2	Recommendation to others	4.19	4.23
Course contents	3	Appropriateness of course structure	4.12	4.17
	4	Reflect industry needs	3.61	3.81
	5	Student-centered implementation	4.33	4.41
	6	Faculty consideration of student needs	4.22	4.32
	7	*Satisfaction in multidisciplinary cooperation*		4.19
	8	*Balancing among disciplines*		4.10
	9	Benefit for professional achievement	3.93	4.01
Self-evaluation	10	Perform with sincere attitude	4.38	4.35
	11	Harmony among team members	4.36	4.23
	12	Active participation	4.34	4.20
	13	Having enough domain knowledge	3.91	4.03
	14	Improving knowledge and skills	4.16	4.13

University support	15	Enough information about supporting fund	4.08	4.22
	16	Appropriateness of expenditure items	4.17	4.23

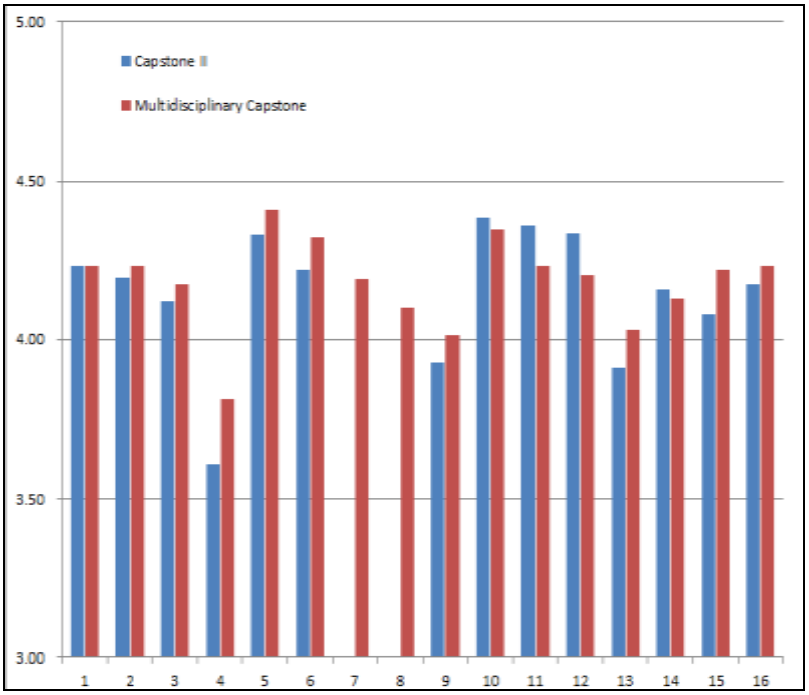

Figure 2. Comparison of students' perception of capstone course experience.

Students who took multidisciplinary capstone course reported the program was satisfactory and meaningful learning experience as they giving little bit higher score on the most of survey items compared to the students who took in-depth capstone. However, means of multidisciplinary capstone group regarding the item 10, 11, 12 in the area of self-evaluation about their learning participation and team activity were lower than in-depth capstone group. This result implies student who have to communicate with faculty members and students from different disciplines might have difficulties in finding way of contribution and collaboration dealing with a multidisciplinary topic.

4. Systemic review for improvement

We applied a systemic framework to reflect our first attempt to provide multidisciplinary capstone experience and to elicit important area for further development. ADDIE model is a famous instructional system design model which has been applied in diverse field of study to design an instructional system. It includes five important areas; analysis, design, development, implementation, and evaluation. According to the ADDIE model, our current practice and support for multidisciplinary capstone course could be analysed as follows.

a) Analysis: In 2013, the project needs for opening a new capstone design course were mainly provided by faculty members. In this process, there were little opportunities to have voices from student and/or industry. In order to increase student motivation for multidisciplinary cooperation through capstone experience, it is important to have a channel for including student's ideas. Through their coursework, extracurricular activities, or daily life experience, student could elicit valuable questions, ideas that could be transformed to capstone project.
b) Design: Delicate issues could arise when the course is involving many professors and students who have different backgrounds and perspectives. Such condition requires more sophisticated consideration with regard to how to design specific instructional components in the

multidisciplinary capstone design course. Dynamic communication and negotiation is required among participating faculty members and students. Thus, faculty development program to help professors deal with team teaching technique, advising methods, and assessing student performance could improve multidisciplinary capstone experience.

c) Development: A number of students, who participated in multidisciplinary capstone course, reported need of electronic portal system that would be used for obtaining specific course information, comparing each team's progress, sharing challenge and learning experience and even building their own e-portfolios. In addition, students suggested that it would be valuable to participate in inter-institutional project that allows them different level of multidisciplinary experiences. This type of student needs implies, we need to develop supportive instructional program such as multidisciplinary design workshop, networking events, and transitional program for career development.

d) Implementation: Compared to the most of university course which has clear course structure and schedule, capstone design course have more freedom in course implementation. This could be beneficial for faculty members or students, but it also could be obstacles to achieve its educational purposes. Thus it could be considered a monitoring system to ensure course quality and balanced time allocation during semester. Many tools such as an interim report regarding on-going project, weekly performance report could be applied.

e) Evaluation – Multidisciplinary capstone design course has its own learning goals that are different with traditional course and previous capstone course. Consequently, it is important to have appropriate evaluation system for assessing students learning outcomes as well as collecting data for further course development. However, it is difficult to build reliable and valid evaluation system especially the course includes different perspectives on learning goals, quality indicators, and learning values. In this context, university could provide a general guideline for assessing student learning process and outcomes. Specific evaluation criteria could be developed by the negotiation of participating faculty members and students according to the project characteristics.

5. Conclusion

Capstone course has been popular setting in the field of engineering education for providing real learning experience that could promote students development of essential competency expected as engineering professionals. As society and academia is changing which put increasing interest and value to the cooperative activities among diverse academic disciplines, multidisciplinary approach in designing and implementing capstone course could be a considerable point for engineering education. According to our experiences at the University of Ulsan, providing multidisciplinary capstone opens new learning opportunities for both students and faculty members. Through multidisciplinary capstone experience, faculty members and students could understand different view-points, techniques, and value systems while they collaborate and sometimes argue with other peoples from different disciplines. Reflection on our current practices, based on the ADDIE model, suggests number of ideas and issues that should be addressed to fortify student meaningful learning experience. In addition, there are needs of conducting empirical studies regarding multidisciplinary attempts in the field of engineering education that enable us to have more in-depth understanding about the complex factors and circumstances in diverse institutional contexts.

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