DESIGN OF A CONSISTENT INTERDISCIPLINARY AND DUAL FACULTY CAPSTONE EXPERIENCE AT THE UNIVERSITY OF MANITOBA

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Abstract - One of the most effective and efficient ways for an engineering program to facilitate compliance with the Canadian Engineering Accreditation Board (CEAB) accreditation criteria is through capstone design projects and courses, [1]. Currently, the University of Manitoba Faculty of Engineering has several capstone design courses; however, each is independently focused on its own respective discipline. The resulting educational experience for students, though rigorous and challenging, is maintained within the boundaries of the students' engineering discipline, thereby neglecting to provide the opportunity for students to work with people from multiple disciplines and across different faculties. This style/mode of education, where students work in silos, arguably does not reflect real world engineering. Program representatives from the Faculty of Engineering at the University of Manitoba agree that the capstones should be more reflective of real life situations.

For this paper, we were hoping to present the research results of a pilot interdisciplinary capstone that was to be launch in the winter of 2017. Unfortunately, the pilot course was not offered because of low student enrollment. So we decided to take an innovative and creative approach to the research. Since, at the University of Manitoba, the Dean of Engineering is also the Dean of the Faculty of Architecture, rather than team with an outside industry focus group, we decided to develop a holistic course with the Faculty of Architecture. The Dean supports this strategy. Interdisciplinary courses are most important because they "...articulate the difference between educational problems and workplace problems" [2]. And allow "(students) persons from different disciplines to work collaboratively and are integrated to combine their knowledge to solve a problem"[3].

This paper explores and explains how that Engineering/Architecture Multidiscipline Capstone and Dual Faculty course will be developed, touches on the early stages of its initiation and implementation, and outlines how the success of the new course will be evaluated.

Keywords: Interdisciplinary; multidisciplinary; capstone course; pilot program, dual faculty.

1. INTRODUCTION

From last year's paper, it was determined through the focus groups and research that this interdisciplinary initiative will be a technical elective offered as pilot course on a voluntary basis between the mechanical and electrical engineering programs at the University of Manitoba. These two disciplines were chosen to launch the initiative because they have worked together closely before and are critical components of any building project design and construction. It was then to be expanded to include the other disciplines after performance qualitative and quantitative evaluations were completed. The course was advertised and was to be launched in January 2017. Eight (8) to twelve (12) students were required to enroll for the initial offering to be viable. The interdisciplinary capstone was scheduled as a late afternoon class to respect students' established timetables and the existing course offering formats. The course would consist of two hours of lectures and three hours of tutorials per week for site visits and meetings with the external group.

An Internal Engineering Faculty Group was formed to provide theoretical instruction on how a project is developed. To insure integration of the learning, the Interdisciplinary teams were to present design lectures to their fellow classmates. This Charrette process was used where students would research each discipline design and present it, in a seminar format, to the class as a lecture. The External Group, which consisted of an actual development business Team, which included: the project Architect; sub-consultants; the developer, and; the general contractor, was to provide the practical application of the design, sharing all the project documentation with the class.

The course structure was to be comprised of a five-part deliverable evaluation including the following stages: review of project criteria; submission of design questions; responses to design questions; project scope change, and; design to accommodate the scope change. The external group had named an actual condominium construction as

the project that would be developed through the course. The internal group representatives had committed to providing design advisory instruction for the winter 2017 course offering.

It was anticipated that the external group would have between 10 and 15 hours contact time with the students over the winter session. To facilitate the external group's tight time frames, meetings with the class were to be conducted at the architect's office. At the final stage of course, the internal disciplines will present their designs to the external team for adjudication. [5].

Throughout the 2016 fall session, internal and external focus group meetings were held to develop the structure, format, and schedule for the winter 2017 Cross Discipline pilot course. See Appendix 1 MECH 4310 Contemporary Topics in Mechanical Engineering-Interdisciplinary Design: Course Structure. The course advertising took place in the fall: bulletin board notifications; third and fourth year students were contacted via E-mail, and; short presentations were carried out in several undergraduate classes. Unfortunately, because of limited enrollment, the course was cancelled, and it was decided thereafter to renew efforts for the following year and take a holistic approach in collaboration with the Faculty of Architecture.

2. BACKGROUND

For the purpose of this paper, a capstone course is defined as "...a project-based learning experience that involves engineering practice through a significant design project whereby student teams meet specific client needs through a creative, iterative, and open-ended design process" [4].

At last year's Conference, we presented our research into recent publications, focus group discussions, and how other institutions approach this challenge, and have identified the following capstone design course key framework goals:

- Should be implemented and managed through a central unit such as the University of Manitoba's Centre for Engineering Professional Practice and Engineering Education
- Should be offered in the final year of a four year Engineering program and should be offered over two terms for at least six (6) credit hours
- Project team members should be from different engineering disciplines and possibly from different faculties
- There must be an strong affiliation with industry or community service

- Student performance evaluations must be based on deliverables with a mechanism for internal team peer assessment
- The final submission should consist of an industrial design report including a design prototype

Last year's paper focused on how the Faculty of Engineering at the University of Manitoba might amalgamate the courses based on the identified goals and create a meaningful capstone design experience for undergraduate students, better prepare them for professional employment, and enhance compliance with the CEAB Graduate Attributes requirements. Finally we presented an approach that allowed the initiative to be piloted on a trial basis as a voluntary option between the Mechanical and Electrical programs at the University of Manitoba. The above framework goals were applied to the proposed pilot course offering.

As an extension of last year's submission, we were going to present the findings from the pilot course design which was to be initiated. Unfortunately, the pilot course was not offered in the 2017 winter session because of low enrollment. So we decided to take an innovative and creative approach to the research. Rather than team with an outside industry development focus group, we decided to develop a holistic course with the Faculty of Architecture. This approach is facilitated by the Dean of Engineering who also serves as the Dean of the Faculty of Architecture, and supports an Engineering/Architectural interdisciplinary dual faculty capstone initiative/strategy. This paper explores how that Engineering/Architecture Multidiscipline Capstone and Dual Faculty course will be developed and evaluated.

3. METHODOLOGY

Besides the research conducted for the CEEA 2016 paper submission, in accordance with University of Manitoba policies, applications were made to the Research Ethics Board as well as the Survey Review Committee. To protect the rights and welfare of human participants in research studies conducted at, or under the auspices of the University of Manitoba, prior ethics review and approval is required by a Research Ethics Board (REB), [6]. In addition, the purpose of the Survey Review Committee is to review proposed surveys, focus groups, and interviews of students, faculty, staff, and alumni to assess quality, timing, adherence to privacy legislation, and to evaluate the usefulness and applicability of them in achieving the University of Manitoba's strategic objectives, [7].

The methodologies that will be used to develop, implement, and evaluate the Eng/Arch capstone course include qualitative and quantitative analyses.

Specially, a January, 2018 before and an April, 2018 after Eng/Arch student surveys will be conducted. The results of the questionnaire will be compared and contrasted to discover how effective students learned, whether their personal course goals were achieved and what could be adjusted to accommodate a better learning environment. From a comparative perspective, an additional student survey will be performed on an undergraduate technology and ethics course to determine if teaching and learning techniques from either course could be applied in the other course to make the teaching more meaningful. The same survey will be given to all three classes, and is shown in Appendix 2, Interdisciplinary Engineering and Architecture Capstone Experience Pilot Course Evaluation Performance Survey. The surveys are structured to determine if students perceive that they have acquired some of the CEAB attributes as a result of taking the course.

Because unbiased research can be performed on students in an unrelated course, a case study analysis will be conducted on a graduate course in engineering design philosophy. One of the case study research question will be “How can the successful teaching techniques of a matured graduate course be applied to an undergraduate multidisciplinary/dual faculty course?” Further research questions will be developed and presented in the next paper.

Peer evaluations in the winter of 2018 will also be employed as a methodology to determine and assess further course development strategies. See Appendix 3, Eng/Arch Interdisciplinary and Dual Faculty Capstone Course Peer Evaluation Winter 2018. Students with low peer reviews will be identified and engagement trends determined to provide a better learning environment.

Students will also provide weekly reflective learnings, which will be reviewed and general trends noted. See Appendix 4, Eng/Arch Interdisciplinary and Dual Faculty Capstone Course Reflective Learning. These trends will provide student feedback on their learning and allow the instructors to communicate with students in a nonthreatening environment. Student suggestions on the course delivery will be recorded and implemented.

4. FINDINGS

Since this paper is focusing on how the extended engineering and architecture course will be developed, the findings presented here are brief, and a more detailed

analysis will be presented in a later paper after the research is completed.

5. NEXT STEPS

For now the template used as a basis for the Eng/Arch course development structure will be comprised of a five-part deliverable evaluation including the following stages: review of project criteria; submission of design questions; responses to design questions; project scope change; design to accommodate the scope change. As referenced above see Appendix 1 MECH 4310 Contemporary Topics in Mechanical Engineering-Interdisciplinary Design: Course Structure. The Architectural Focus Group has named a boutique hotel project as the project that will be developed through the course. The Engineering Focus Group representatives have committed to providing design advisory instruction for the upcoming winter 2018 course.

At this time it is anticipated that the external group will have between 10 and 15 hours contact time with the students over the winter session. To facilitate the external group's tight time frames, meetings with the class will be conducted at the architect's office. At the final stage of course, the internal disciplines will present their designs to the external team for adjudication.

6. CONCLUSIONS

This paper has focused on how a multidisciplinary Engineering and Architectural capstone course has been proposed for the Faculty of Engineering and the Faculty of Architecture at the University of Manitoba in order to create a more meaningful capstone design experience for undergraduate students, better prepare them for professional employment, and enhance compliance with the CEAB Graduate Attributes requirements.

From the development of this conference paper, I have learned the following important lessons:

- Course work material such as the following processes: peer evaluations; weekly reflective learnings, and; personal course diaries and logs can be extremely useful to develop a dual faculty course
- To stay on task, I need to create and follow and review a rigid course log to stay focused on the big picture
- I look forward to developing the engineering and Architecture capstone course and nurturing it along the way to create a meaningful and practical course that Engineering and Architectural students will benefit from taking.

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Architectural Focus Group: Dr. Carlos Rueda, and; Neil Minuk

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APPENDIX 1: MECH 4310 CONTEMPORARY TOPICS IN MECHANICAL ENGINEERING-INTERDISCIPLINARY DESIGN: COURSE STRUCTURE

Stage	Week	Date	Activities	Essential Team Development	Deliverables/Review Requirements	Learning Objectives	Location
Stage I Course Introduction, Understanding of the Project and the Process (20% Grade)	1	Tues 1/13/2017	No Classes				
	2	Wed 1/18/2017	Mark Penner (Qualitative Perspective, Team Development, Business Case, Land Choice Decision, Market Studies, Impact Studies, Environmental Studies, Funding Processes, Sasa Radulovic: Architect's Perspective, Design Concept, Concept Development, Introduction of the drawing package by the Project Team)	Carolyn/Mark/Sasa/Ted	Preliminary Architectural Plans, Site Layout, Project Schedule, Preliminary Project Budget, Preliminary Plans for Site Review, Geotechnical, Environmental, Preliminary Plans for Site Review (Detailed engineering drawings)	Students will understand how projects come about, how the developer makes decisions, how funds are raised, how the professional team is put in place. Students will have with a set of preliminary design documents (not including the detailed engineering drawings)	5468796 Architects
	3	Tues 1/24/2017	Review of the drawings	TBD	An understanding of the drawings	With the aid of the internal team, students will prepare an on "lead" architectural drawings	ETIC E2-221
	4	Wed 1/25/2017	Building site tour	Ted/Sasa	Orientation and verification of documents with as-built	Students will understand the relationship between drawings and the as built environment. Students will understand how the building systems were constructed	IBM Condominium Project
Stage II Review of Codes, Speakers, Review Fire Protection (John Frye: Permit Requirements - Rick Derksen City of Winnipeg)	5	Tues 1/30/2017	Review of Codes, Speakers, Review Fire Protection (John Frye: Permit Requirements - Rick Derksen City of Winnipeg)	TBD	Access to building codes	Students will understand the role of codes in the design and construction of buildings	ETIC E2-221
	6	Wed 1/31/2017	Julien Lavergne - Engineering Perspective, Structural Perspective, Mechanical Perspective, Electrical Perspective, Environmental Perspective, Interaction with the Designer, Builder, Subcontractors	Julien/Ted/Mechanical/Electrical	Engineering/Subcontractor Drawings	Students will understand how the detailed design of a building are achieved and the roles within engineering/architects in this achievement	UDA Structural Engineers
	7	Tues 2/6/2017	Review of Design	TBD	Preliminary Load Calculations, HVAC/Mechanical, Electrical/Lighting/Plumbing	Students will review the detailed design documents including verification of the calculations and conformance with code. Students will develop a set of questions to be asked to the external team	ETIC E2-221
	8	Wed 2/7/2017	Questions/Answer of the Original Design	Mark/Julien/Sasa/Ted/Mechanical/Electrical	Final presentation, Presentation of List of Engineering Design Questions/Critique Graded by the Project Team	Students will give experience in using pin-ups of the drawings to present their questions to the Project Team. Student performance will be evaluated with input from the development team based on a marking rubric.	5468796 Architects
Stage III Detailed Engineering Calculations	9	Tues 2/14/2017	Detailed Engineering Calculations	TBD	Detailed Design Calculations	Students will understand how to perform design calculations	ETIC E2-221
	10	Wed 2/15/2017	Review Construction Techniques	Ted		Students will understand the processes used to construct buildings using a prefabrication process	Hot Custom Profiles
	11	Tues 2/21/2017	Reading Week No Classes				
	12	Wed 2/22/2017	Reading Week No Classes				
Stage IV Preparation to Stage I Questions (20% Grade)	13	Tues 2/28/2017	Preparation of Design Presentation	TBD	Design presentation	Students will gain experience in preparing a final design concept presentation	ETIC E2-221
	14	Wed 3/1/2017	Review presentation report with students. Presentation of the design change	Mark/Sasa/Julien/Ted	Presentation Report (PowerPoint) Results of the analysis of the original design Graded by the Project Team	Students will experience a formal design review presentation. Student performance will be evaluated with input from the development team based on a marking rubric.	5468796 Architects
	15	Tues 3/7/2017	Preliminary Review of Design Change	TBD	Discussion points for the design change	Students will gain experience with a major design change part way through a construction process	ETIC E2-221
	16	Wed 3/8/2017	Change Scenario Discussion/Options Feasibility	Mark/Sasa/Julien/Ted	Lead Discussion	Students will understand the issues involved in a major design change	5468796 Architects (?)
Stage V Change Scenarios (20% Grade)	17	Tues 3/14/2017	Develop preliminary proposal	TBD	Preliminary Proposal	Students will develop design changes	ETIC E2-221
	18	Wed 3/15/2017	Review proposals, Finalize Accepted Options	Mark/Sasa/Julien/Ted/Mechanical/Electrical	Final Presentation Report: Options Scenario Description and Integration Graded by Project Team	Students will experience a pin-up session with design changes. Student performance will be evaluated with input from the development team based on a marking rubric.	5468796 Architects (?)
	19	Tues 3/21/2017	Develop solutions	TBD	Problems and Solutions Analysis	Students will develop details of their solution	ETIC E2-221
	20	Wed 3/22/2017	Develop solutions	TBD	Problems and Solutions Analysis	Students will develop details of their solution	ETIC E2-221
Stage VI Problem/Solution Analysis (20% Grade)	21	Tues 3/28/2017	Develop solutions	TBD	Problems and Solutions Analysis	Students will develop details of their solution	ETIC E2-221
	22	Wed 3/29/2017	Project Change Realization	Mark/Sasa/Julien/Ted	Final Presentation Report: Final Design Drawing, Description Specific As Well as Integrated, Graded by the Project Team	Students will discuss design changes with Project Team. Student performance will be evaluated with input from the development team based on a marking rubric.	5468796 Architects (?)
	23	Tues 4/4/2017	Prepare Presentation	TBD	Problems and Solutions Analysis	Students will finalize details of their solution	ETIC E2-221
	24	Wed 4/5/2017	Development Team to Review and Confirm Report and Overview	Mark/Sasa/Julien/Ted/Mechanical/Electrical	Presentation Report (PowerPoint) Final Design Drawing, Description Specific As Well as Integrated, Graded by the Project Team	Final presentation of the design changes. Student performance will be evaluated with input from the development team based on a marking rubric.	5468796 Architects (?)
Stage VII Design Drawings and Report (20% Grade)	25	Tues 4/11/2017	Complete Final Report				ETIC E2-221

APPENDIX 2: INTERDISCIPLINARY ENGINEERING AND ARCHITECTURE CAPSTONE EXPERIENCE PILOT COURSE EVALUATION PERFORMANCE SURVEY

For brevity, the preamble which contains research purpose, ethics approval requirements, survey processing guidelines, and additional instructions, has been omitted here.

Instructions: Please circle the letter or letters of your choice or choices.

- What years of the Engineering program are you currently enrolled? 1, 2, 3, 4, +5
- What is your Engineering Discipline? Biosystems, Civil, Electrical and Computer, or Mechanical
- Have you previously taken any of the following discipline specific capstone courses:

(Yes/No)

- MECH 4860 Engineering Design
- ECE 4600 Group Design Project
- CIVL 4590 Capstone Design Project
- BIOE 4580 Design Trilogy II
- BIOE 4580 Design Trilogy III;

- Would you consider taking an interdisciplinary capstone course?

Never/Not Likely; Don't Know; Likely/Definitely

- How do you determine your course learning success?

Select as many as applicable:

- a. Marks
 - b. Positive application of course material to everyday life
 - c. Positive application of course material to job (summer/coop, etc.)
 - d. Other (Please specify):
6. How do you learn most effectively and efficiently? (Select as many as applicable)
- a. Researching on your own
 - b. Researching in teams,
 - c. Completing assignments on the material covered
 - d. Giving lectures to fellow class mates
 - e. Working with industry sponsors
 - f. Open ended discussion lectures
 - g. Others methods please specify
7. For students who have already completed an interdisciplinary capstone design course, were you better able to solve complex engineering problems based on the course learnings?

Never/Not Likely; Don't Know; Likely/Definitely

8. For students who have already completed an interdisciplinary capstone design course, were you better able to design solutions for complex, open-ended engineering problems with appropriate attention to economic, environmental, cultural, and societal considerations based on the course learnings?

Never/Not Likely; Don't Know; Likely/Definitely

9. For students who have already completed an interdisciplinary capstone design course, were you able to communicate complex engineering concepts within the profession and with society at large? (This includes your student interdisciplinary capstone team, the internal focus group, as well as your external focus group.)

Never/Not Likely; Don't Know; Likely/Definitely

10. For students who plan to complete the interdisciplinary capstone course, do you expect that completing the course will give you an ability to solve complex engineering problems based on the course learnings?

Never/Not Likely; Don't Know; Likely/Definitely

11. For students who plan to complete the interdisciplinary capstone course, do you expect that completing the course will give you an ability to design solutions for complex, open-ended engineering problems with appropriate attention to economic, environmental, cultural, and societal considerations based on the course learnings?

Never/Not Likely; Don't Know; Likely/Definitely

12. For students who plan to complete an interdisciplinary capstone design course, do you expect that completing the course will give you an ability to communicate complex engineering concepts within the profession and with society at large? (This includes your student interdisciplinary capstone team, the internal focus group, as well as your external focus group.)

Never/Not Likely; Don't Know; Likely/Definitely

APPENDIX 3: ENG/ARCH INTERDISCIPLINARY AND DUAL FACULTY CAPSTONE COURSE PEER EVALUATION - WINTER 2018

In the space below, honestly evaluate the other members of your class using the provided criteria and ranking system. In the case where you feel a group member's contribution was unsatisfactory, please provide an explanation in the comments.

Evaluations are to be submitted by email to Bill DeGagne and the TAs no later than Midnight on Friday, April XX, 2016.

Evaluator's Name: _____ Group: _____ No.: _____.

Class Member 1:

1. Carried a fair share of the workload
2. Completed all assigned tasks with a high degree of quality
3. Completed all assigned tasks within a timely manner
4. Was overall pleasant/easy to work with
5. Was overall a valuable contributing member

Additional comments (optional):

APPENDIX 4: ENG/ARCH INTERDISCIPLINARY AND DUAL FACULTY CAPSTONE COURSE REFLECTIVE LEARNING - WINTER 2018

Students will submit Reflective Learning (RL) comments. Each should contain your personal reflection, showing your understanding and critical thinking of one or more of the following:

- How the specific week(s) course work applies to you, and lessons learned
- How the week(s) course work could be adapted to your work or personal context
- How the week(s) course work may be relevant to you or your specific field.

Whatever you choose to write should contain some depth of thought – a very personal reflection. Each RL should be concise and between 100 to 150 words. Reflective learnings longer than 150 words may not be marked.