Pedagogical Skill Development Through the Horizontal Integration of a Second-Year Engineering Curriculum

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Kyle obtained his B.A.Sc. in Civil Engineering with a Certificate in Structural Engineering at the University of Waterloo in 2015. He is now furthering his knowledge in the discipline of structural engineering by pursuing a research based master's (M.A.Sc.) degree co-supervised by Dr. West and Dr. Walbridge. Kyle's research focuses on understanding the fatigue behaviour of slip-critical shear connectors used in composite bridges between steel girders and precast concrete slabs. The proposed research will involve both experimental and numerical components. Scaled test specimens will be fabricated and loaded cyclically to assess the fatigue life and performance of the shear connectors and a finite element model of the specimens will be generated to evaluate the performance numerically. This research is expected substantiate the reliability of using fewer required shear connectors, rendering a more efficient design.

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Pedagogical Skill Development through Horizontal Integration of a Second Year Engineering Curriculum

Abstract

This paper explores the use of a comprehensive design, management and construction project as a pedagogical teaching instrument for second year engineering students, simulating the challenges and responsibilities they will face in the professional engineering consulting discipline. The primary objective was to educate students in an interactive manner spanning diverse fundamental skillsets by having them analyse a problem, evaluate various design solutions and apply their knowledge in a collaborative group effort.

Students were randomly arranged into groups of four with the task of designing, constructing, and testing a bridge out of wood and plastic stir sticks subject to material, dimensional and cost limitations. Students were required to exercise and integrate their knowledge of four compulsory second year courses to arrive at an optimal design solution. First proposed by the University of Cincinnati, this amalgamation of courses specializing in various disciplines, taught concurrently within a specified time duration is termed horizontal integration. This differs from vertical integration where knowledge in a specific discipline is accumulated through various stages of increasing difficulty over the course of several time intervals.

The four courses pertinent to this project include: Solid Mechanics, Probability and Statistics, Structure and Properties of Materials and new to this year; Transportation Principles and Applications. The Civil Engineering department at the University of Waterloo developed a new curriculum whereby the Transportation Principles and Applications course replaced Economics and Life Cycle Analysis, which is now taught during a later academic semester. In response to this curriculum change, the project was modified from last year by decreasing the emphasis on the economic and lifecycle analysis of the project, more heavily focusing on transportation design aspects. This was achieved by changing the proposed bridge location from a crossing with horizontal approaches and a well-defined clear span distance to a flood plain scenario with sloping approaches on either side. Students are challenged with the task of arriving at an optimal design solution considering the balance between a variable bridge clear span distance and the consequent volume of excavated material required for their selected clear span while respecting roadway design regulations.

The project was designed such that students were allowed to express their creativity, making their own design decisions with limited restrictions as well as gain experience with commercial structural analysis software. Moreover, the project had the intent of demonstrating the value of teamwork, subjecting students to an environment where they were required to work with others. Feedback was assimilated from previous year's students to further improve the effectiveness of this pedagogical teaching instrument. Students from the previous year indicated difficulties working with peers with conflicting personalities. To mitigate this issue, a teamwork building workshop was established this year, teaching students how to recognize and respect differences in personality traits and how to capitalize on the inherit benefits of each. Further, a preliminary design report submission was incorporated this year to allow for intermittent feedback, allowing for support to students where the instructor felt necessary.

1.0 Introduction

Students in the University of Waterloo’s (UW’s) Civil Engineering program are exposed to open-ended design projects in their first and final years of study. The gap between these years needs to be filled to continuously stimulate creativity and encourage students to recognize the important connection between what is discussed in lectures and how this knowledge can be used to help society. Recent investigations have suggested that horizontal integration is one approach for retaining this knowledge, particularly as related to broader, multi-sectoral concepts (Barella and Watson, 2015).

Second year Civil Engineering students at UW take five courses in the first term of their second year. An Integrated Design Project (IDP) that integrates four of these courses was developed to provide the students with insight to a variety of problems and situations handled by engineers on a daily basis. One of the primary objectives of the IDP was to familiarize students with design methodologies and solution iteration earlier in their undergraduate career, advancing their capacity to make independent decisions. Integrating courses into a single project illustrates the necessity of understanding and combining a wide variety of concepts to effectively arrive at comprehensive solutions. Thus, it is expected that efforts to increase the education potential of students in their second year will significantly improve their performance in designing and delivering their capstone project in their final year of study.

The IDP used to integrate these courses was a stir stick bridge design and construction group project. The IDP involved students in designing, analyzing and constructing a bridge made of wood or plastic stir sticks, subject to requirements, which govern the material selection, the geometric constraints of the design and the economics of the project as a whole.

Student feedback indicated that the IDP benefited them positively, furthering their engagement in the learning of their second year courses. At least 60% of student respondents in a survey conducted subsequent to the completion of the IDP in 2015 and 2016, indicated that they would benefit from working on similar projects in other courses. Also, student feedback confirmed that the IDP aided in bridging the gap between academic theories to practical design applications.

This paper describes in detail the formulation and delivery of a comprehensive design project, which brings together the core concepts discussed within the second year Civil Engineering program at UW. This paper highlights the successes observed and addresses the challenges encountered while providing recommendations for future efforts.

2.0 Literature Review

The use of a comprehensive group project as a pedagogical teaching instrument for students has been proposed by several researchers as an innovative mechanism to educate students in an interactive manner (Orkwis et al., 1997, Snyman and Kroon, 2005 and Barragán et al., 2005). Projects typically require students to analyse a problem, evaluate various design solutions and apply their knowledge in a collaborative group effort to arrive at a solution that they deem acceptable. The efficacy of the group project is further improved by employing horizontal integration.

Horizontal integration is the use of a concept, such as a design project to link diverse courses that are concurrently taught during a specified time period, such as a semester. This is different from vertical integration, which is the building of knowledge in a specific discipline through various stages of increasing difficulty and complexity, such as the entirety of undergraduate studies (Hassan, 2013). The simultaneous use of these two types of integration was proposed by the University of Cincinnati to enhance the design capabilities of students in an Aerospace Engineering program by having them work on projects which integrate the various aspects of design throughout their undergraduate studies, as well as building upon prior knowledge from semester to semester (Orkwis et al., 1997).

The combination of horizontal and vertical integration in education is common in the health and medical sectors. Vertical integration is employed to reinforce the basic knowledge of various subjects taught in previous academic terms and horizontal integration allows students to rehearse newly learned skills and subject matter. Snyman and Kroon (2005) presented work on implementing vertical and horizontal integration in dental education through the use of case studies based on real-world situations. Similarly, Barragán et al. (2005) utilized a medical case-study based horizontal integration project where students worked in groups of eight to develop a solution to a proposed case study. The solution required the integration of a variety of disciplines including histology, embryology, molecular biology and several more.

A notable variation of horizontal and vertical integration was implemented by Giralt et al (2000). This adaptation involved a first year engineering project, which utilized horizontal integration of various topics covered in the first year curriculum to solve a proposed design problem. Vertical integration was incorporated by having fourth year students enrolled in a project management course serving as the project managers for the first year project groups. This exposed the first year students to advanced project management techniques without requiring any additional coursework. A survey found that the first year students learned effective teamwork, time management, and reliability in delivering on deadlines, while the fourth year students primarily learned to lead a team with varying backgrounds and technical skills. One of the critical feedbacks was the lack of communication in regards to expectations of the first year instructors and the fourth year students.

An investigation conducted by Knight et al. (2007) demonstrated a strong correlation between program enrollment retention and the ability of first year engineering curricula to connect academia to the professional practise of engineering as a career. The investigation involved requiring first year engineering students to participate in a comprehensive engineering project. Students were tasked with the challenge of working in a team environment to design a solution to an open-ended engineering problem, construct and test their prototype. Here, 5,070 first year engineering students from sixteen US institutions were surveyed over the course of 8 years. The percentage change in student retention (as a percentage) varied from school to school. Student retention increased by as much as 80% relative to when the institutions did not require first year student participation in a comprehensive and integrated engineering project (i.e. from 50% retention to 90% retention).

One of the primary goals of the IDP is to enable student' learning beyond achieving a remembering level in the cognitive domain. Bloom et al. (1956) categorized the cognitive domain into six categories and organized them from the simplest to most complex. They are: knowledge, comprehension, application, analysis, synthesis and evaluation, respectively. This taxonomy was later revised by Anderson et al. (2001), who changed the category descriptors to verbs and swapped the order of the two most complex categories. They also redefined the cognitive domain from Bloom's original two dimensional hierarchy of increasing cognitive complexity to a three dimensional intersection of the Cognitive Process Dimension and the Knowledge Dimension. The categories defining each dimension are shown in Figure 1.

Figure 1. Current Revision of Bloom's Taxonomy.

***Figure credit: Iowa State University, Center for Excellence in Learning and Teaching* (Heer, 2012)**

The Cognitive Knowledge Dimension differentiates four types of knowledge that students may be expected to obtain, whereas the Cognitive Process Dimension illustrates the hierarchy of increasing cognitive complexity proposed by Bloom. The professors that delivered the IDP described herein agreed that most of the second year students that participated in the IDP demonstrated the capacity to achieve a "Design" learning objective as defined in Figure 1. This learning objective is achieved from effectively demonstrating a "Create" level on the cognitive process dimension and a "Procedural" level on the knowledge dimension. It is believed that all students were successful in creating a logical solution to the design challenge that was posed to them by assimilating various facets of knowledge while effectively implementing procedures and algorithms discussed in class.

3.0 Problem Definition

Undergraduate engineering programs do not necessarily expose students to open-ended design problems, allowing them to express their creativity and, ultimately, make independent decisions. Coursework could predominantly involve regurgitation of problems similar to those discussed in class. In such cases, student learning potential is limited to the "Apply" learning objective on the cognitive process dimension proposed by Bloom. Such curricula do not promote independent bridging of the gap between what is discussed in lectures and how this knowledge can be used for the benefit of society. This connection is paramount in the development of professional engineers (Figueiredo, 2017, Gary, 2015, Noordin et al., 2011). Therefore, the motivation for assigning the IDP to second year engineering students was primarily to give students an introduction to design, cost analysis, and other aspects of typical engineering responsibilities, which must be considered in real-world engineering projects.

The IDP was open ended to enable student creativity and encourage iterative solution development, evaluating arguments for and against each design decision from start to finish. Moreover, by horizontally integrating the four courses, students benefited from understanding the value of learning each subject and how they are all pertinent to the development of a comprehensive solution. The IDP has similar requirements to a capstone project done in fourth year, which encapsulates the entirety of the students' engineering education. It is anticipated that student involvement with the second year IDP will better prepare them for their capstone project in their fourth year.

The IDP was expected to further illustrate the value of teamwork and provide students with the experience of working with others. The intent of this collaboration was to encourage students to share ideas and build off each other's thoughts to create an optimal design. Finally, group work allowed for the students to gain time management experience in setting and meeting deadlines, which must be completed both individually and by the group as a whole.

4.0 Horizontal Integration of Courses

Students were randomly arranged into groups of four with the task of designing and constructing a bridge out of wood and or plastic stir sticks, subject to material, dimensional, and cost limitations for their IDP. Students were required to exercise and integrate their knowledge of four compulsory second year courses to arrive at an optimal design solution.

The four courses pertinent to the IDP include: Statics and Solid Mechanics, Probability and Statistics, Structure and Properties of Materials, and Engineering Economics. The University of X, Civil and Environmental Engineering department, developed a new curriculum for 2016, whereby the Transportation Principles and Applications course replaced Engineering Economics, which is now taught during a later academic semester. In response to this curriculum change, the IDP was modified from 2015 by decreasing the emphasis on the economic and lifecycle analysis of the project, more heavily focusing on transportation design aspects.

The design problem students were faced with in 2015 was to design, construct and test a bridge made from the provided wooden and or plastic stir sticks as well as threads of their choice. While the decisions pertaining to the design of the bridge were as unconstrained as possible to allow for student creativity, several constraints were established to enable a fair competition between the bridge designs. Students were required to design their bridge such that the span was a minimum of at least 750 millimetres (mm) and a maximum of 900 mm. No part of the bridge was permitted to make contact with the vertical abutment faces and the maximum height of the bridge was limited to 400 mm above the supports and 200 mm below the supports. Also, the bridge deck was required to support a vinyl roadway with adequate space to pass a vehicle and a load plate. The weight of the bridge was required to be greater than 200 grams (g) but not more than 1000 g. It was required that the materials used for construction of the bridge were only those provided by the course instructor and were limited to the quantity provided by the instructor. An exception to the limitation of materials was that students were permitted to use any thread of their choice, in any quantity of their choice. Efforts were made to further increase the pedagogical value of the IDP by simulating a real life conflict that could occur as a consequence of trade-offs between design criteria and cost. The group that achieved the highest accuracy in their calculations received +1% in their Solid Mechanics course. However, achieving higher accuracy required increasing their cost through the purchase of additional material testing data sets. This increase in cost proposed a trade-off for students as the group with the lowest life cycle cost received +1% in their Engineering Economics course. Figure 2 shows a diagram of the bridge setup requirements.

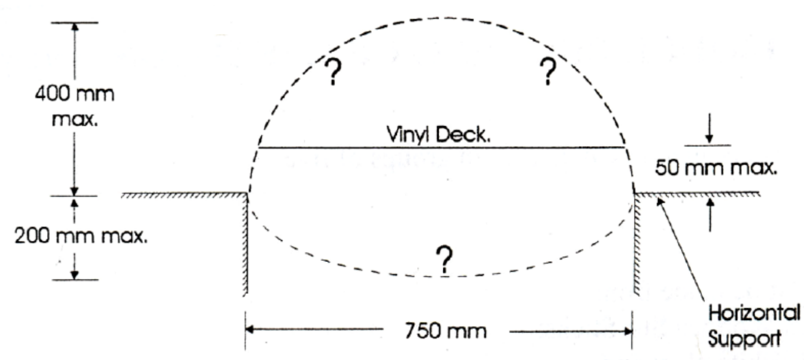

Figure 2. Diagram of bridge design requirements for 2015.

The design problem that the students were faced with in 2016 was very similar to that in 2015. However, it was modified to accommodate the curriculum change. To place more of an emphasis on transportation design, the proposed bridge location was changed from a crossing with horizontal approaches and a well-defined clear span distance (Figure 2) to a flood plain scenario with sloping approaches on either side and a variable clear span distance. This is illustrated in Figure 3.

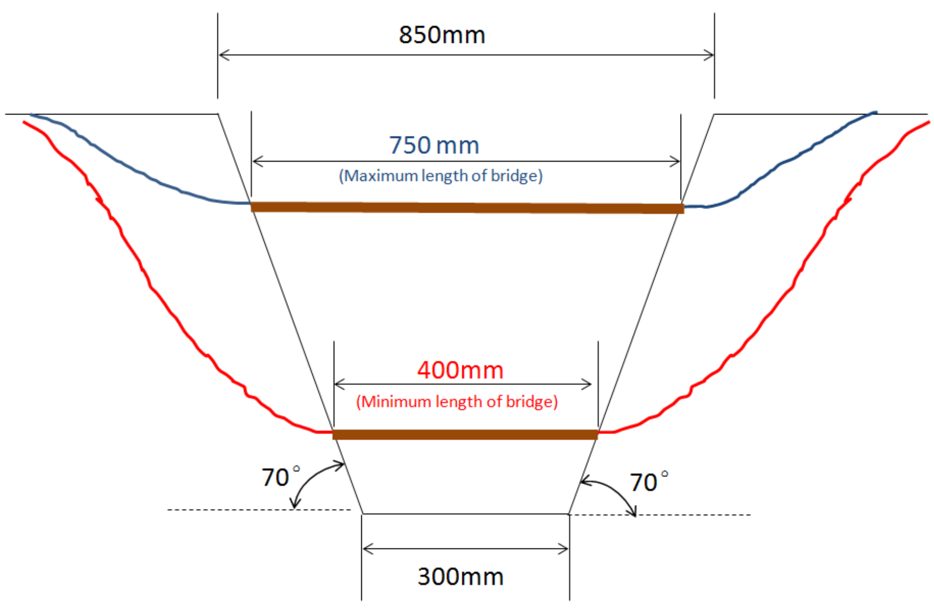

Figure 3. Diagram of bridge design requirements for 2016.

Students were challenged with the task of arriving at an optimal design solution considering the balance between a variable bridge clear span distance and the consequent earthwork volume required for their selected clear span, while respecting roadway design regulations such as roadway grades. Moreover, to accommodate this project definition, the minimum and maximum clear span distances were changed to 400 mm and 750 mm respectively.

The primary deliverables for this course were the bridge itself and a report describing the design, analysis and construction process. The bridges were assessed based on its load capacity and on the accuracy of the predicted value of the ultimate load. Marks were deducted for predictions not falling within +/- 20% of the actual load sustained by the bridge and marks were deducted if the ratio of the ultimate strength of the bridge (as per the test result) to the weight of the bridge squared (strength-to-weight ratio) was less than 250. Bonus marks were provided to teams whose predicted values were within 10% of the actual failure load. The bridges were ranked based on their strength-to-weight ratios.

The Solid Mechanics section of the IDP required students to employ their understanding of mechanics to design the shape and geometry of their bridge. The groups were required to analyze their bridge design using a structural analysis software, such as SAP2000. Moreover, students performed calculations by hand using first principles learned in their Solid Mechanics course to validate the results from the structural analysis software. Using these two sources of information, the students were to identify the critical member in their bridge and predict the ultimate load the bridge would be able to sustain. The ultimate strength-to-weight ratio of the bridge was then predicted and the design was iterated until this ratio was larger than 250.

The knowledge contribution that the Engineering Economics course offered to the students in 2015 enabled them to calculate the life-cycle cost of their stir stick bridge. An assumed service life of 75 years was adopted. Students were to assume that the bridge would deteriorate over time, losing structural capacity and thus require rehabilitation prior to the structural capacity diminishing below levels required to sustain the service load of a vehicle. The initial cost of the bridge would be based on the cost of the materials provided (glue, wood sticks and plastic sticks), labour costs and the purchase cost of data acquisition. All groups were initially given one set of material testing data however, students were permitted to purchase laboratory time to conduct further strength tests, reducing the standard deviation of the various material properties. Rehabilitation costs for the bridge were based on anticipated materials and labour, which was assumed to be 60% of the material costs. Annual costs were also assessed to account for standard operations and maintenance.

The primary contribution that the Structure and Properties of Materials course offered to the IDP was the understanding of the behaviour, strengths and weaknesses of the materials permitted for construction. The knowledge of the predicted performance of wood and plastic from a theoretical standpoint, in addition to material testing was vital in students making educated material selection decisions. The material testing was conducted early in the academic term so that students would have access to the necessary data prior to making decisions regarding material selection. Students were required to demonstrate their understanding of the material properties including failure loads, ductility and variability between specimens of the same material.

The Probability and Statistics course augmented the Structure and Properties of Materials course as it offered the means required for students to quantitatively compare the provided testing data from a statistical standpoint. This was achieved by comparing the mean strength of each of the materials evaluated during their testing program. Students were required to provide a graphical representation of the materials testing data to demonstrate the mean, standard deviation, and distribution of the data. They were also asked to draw inferences about the relative performance of the materials. All assumptions and analyses had to be stated and justified, and the students were asked to investigate if additional data were required.

New to 2016, the Transportation Principles and Applications course was essential for students to determine an appropriate geometry of the roadway surface in their designs. The approach roadways on either end of the bridge were to be designed in such a manner that the slopes were accommodating for the safe passage of trucks. Another important consideration addressed by the theories discussed in the Transportation Principles and Applications course is the cost associated with the excavation or fill requirements to prepare the embankment for the roadway approach on either side of the bridge. The quantity of excavated or fill material required is directly proportional to the bridge span decided upon by the students. Students were challenged with the task of attempting to minimize the length of the bridge, reducing material costs while simultaneously minimizing the amount of fill material required. This challenge was intentionally incorporated to once again simulate a real life conflict, requiring students to evaluate options and allocate efforts to satisfy all constraints while optimizing items they deemed critical to achieve their objectives.

Each course provided insight on certain aspects of the bridge design which were amalgamated to form a complete and thorough solution. These various aspects are all dependent on one another and are heavily interrelated allowing for an effective integration within the IDP. Figure 4 and 5 show how each course and their individual requirements affects the other courses and the overall goal of the IDP for 2015 and 2016 respectively.

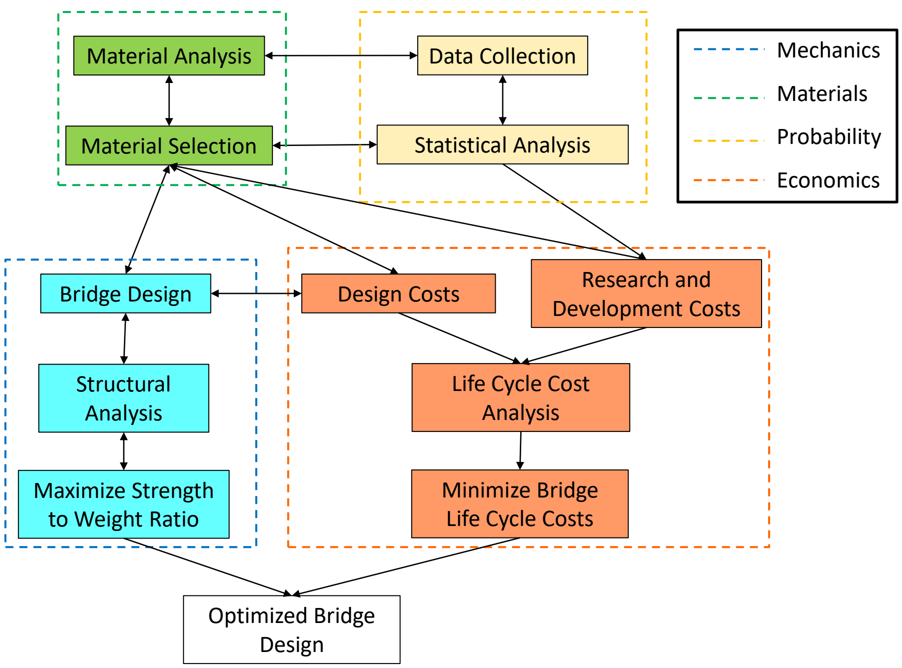

Figure 4. Diagram of integration between the four courses for the IDP in 2015.

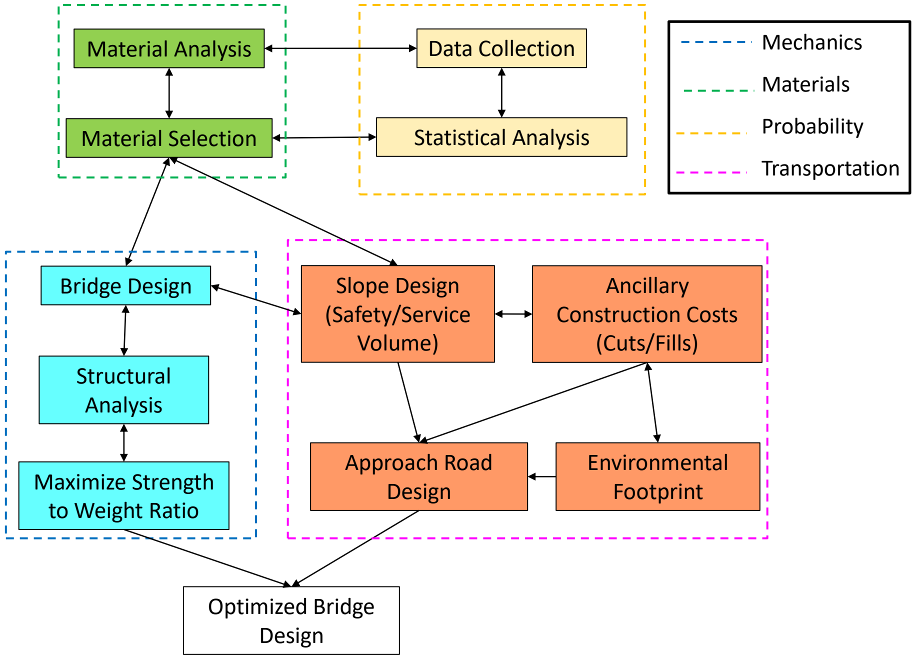

Figure 5. Diagram of integration between the four courses for the IDP in 2016.

5.0 Student Feedback and Discussion

Students were surveyed both prior to the beginning of the IDP and following completion. The results of these surveys were compared to understand how the mindset of the students changed over the course of the IDP as well as to evaluate the effectiveness of the project objectives.

Initially, students were asked a variety of questions regarding their understanding, goals and anticipated outcomes of the IDP. The results of this initial survey for 2015 and 2016 are summarized in Figure 6.

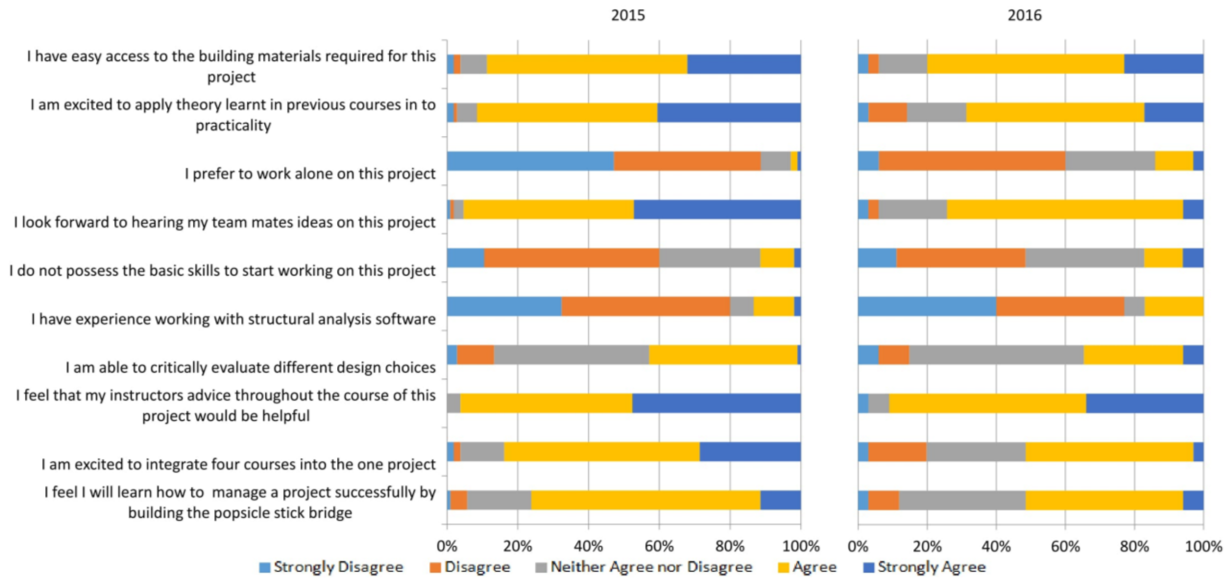

Figure 6. Results of survey conducted prior to the start of the IDP.

As illustrated in Figure 6, students from each year had similar initial opinions prior to commencing the IDP. However, it is important to note that 106 out of 120 students participated in the preliminary survey conducted in 2015, while only 35 out of 121 students participated in the preliminary survey conducted in 2016. More than 80% of students in 2015 and 50% of students in 2016 at least agreed that they were excited to integrate four courses into one project and apply theory to a practical project. This contrast in increase in reported excitement could be associated to the fact that the pre-survey in 2015 was conducted after the IDP had been introduced to the students, with the instructors for the four courses all present. At this time, the connection between the four courses was made explicit to the students and there was a strong collaboration between the instructors. This did not happen in 2016, as communication between the four instructors was limited until later through the term.

Furthermore, respondents indicated that working with a group was preferred with more than 85% of respondents in 2015 and 60% of respondents in 2016 at least disagreeing with preferring to work alone. Interestingly, approximately 60% of respondents in 2015 and 50% of respondents in 2016 at least disagreed with the statement that they did not possess the basic skills to commence work on the project. This is important to note as recognizing one's own shortcomings and understanding that assistance is required is very important in consulting.

The results of this survey show that before commencing the IDP, students were looking forward to several of the pivotal components of this project such as the teamwork aspects and the integration of courses to simulate real project considerations. Additionally, it appeared that the technical objectives of the IDP were set appropriately, with respondents indicating some basic knowledge in the subjects but acknowledged that further education is required in certain areas.

Following the conclusion of the IDP, students were surveyed once again. The questions included opinions of teamwork, project management, application of theory, application of the various courses within the IDP and overall opinions on the IDP. Figure 7 presents the results of the post-IDP surveys conducted in 2015 and 2016.

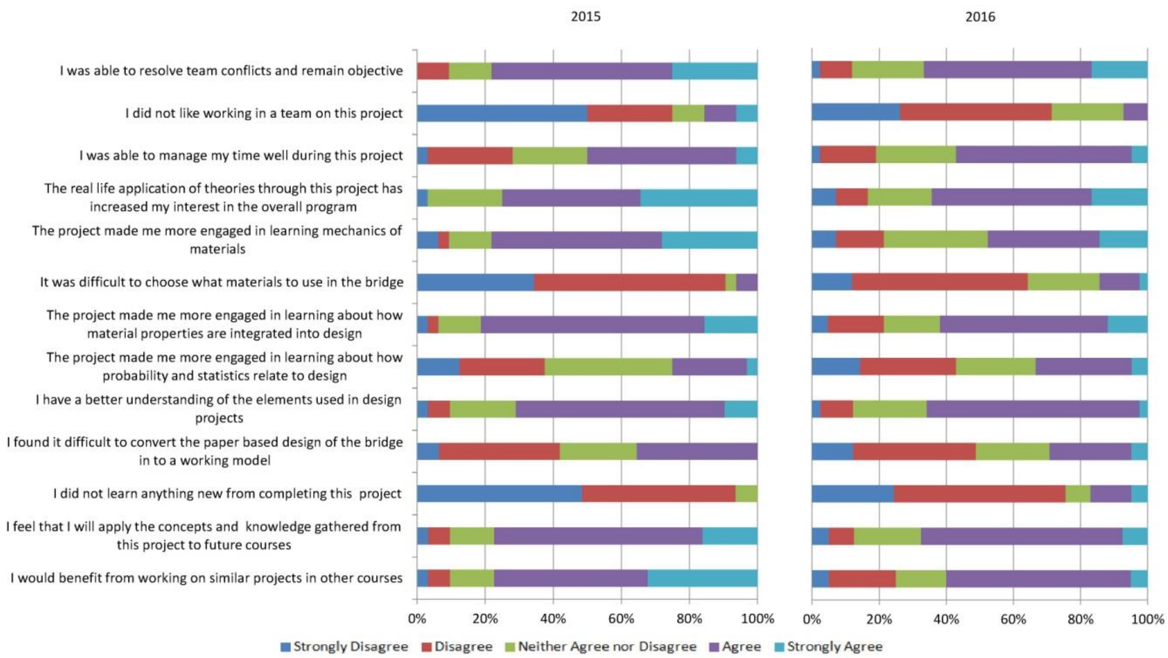

Figure 7. Results of survey conducted upon completion of the IDP.

Unlike the preliminary survey, students from each year had dissimilar opinions subsequent to the completion of the IDP. Once again, it is important to note that 32 out of 120 students participated in the concluding survey conducted in 2015 while 42 out of 121 students participated in the concluding survey conducted in 2016. While more than 60% of respondents in 2015 indicated that the IDP made them more engaged in learning the various courses involved in the project, only 47% agreed in 2016. Similarly, respondents in 2015 indicated they largely believed that the real life application of theories through the IDP increased their interest in the overall program (75%) whereas this level of interest was reduced to 57% in 2016. In terms of the student's enthusiasm towards group work, an improvement was observed as 84% of respondents acknowledged that they enjoyed working in a team in 2015 whereas this number was increased to 93% in 2016. This progression might be attributed to a teamwork building, workload distribution and conflict resolution workshop that was integrated into the curriculum in 2016. However, a decrease in the percentage of respondents who indicated they were able to resolve conflicts and remain objective was observed from 78% to 67% in 2015 and 2016 respectively. These conflicting responses indicate that while students largely enjoyed working in groups, many believed that conflict resolution is an area that requires further guidance.

Overall, 77% of respondents in 2015 indicated that they believed that they would benefit from working on similar projects in other courses. This number was reduced to 60% in 2016. One possible explanation for the decrease in respondent enthusiasm towards the IDP is the fact that course instructors were better prepared and more organized in 2015 than they were in 2016. New instructors taught three out of the four pertinent courses in 2016 and were therefore unfamiliar with the IDP. Furthermore, the participating instructors in 2015 collaborated heavily both amongst themselves and with the students. Students in 2016 found it very difficult to understand the interdependencies relating the four integrated courses as the connections were not made explicit to them from the course instructors.

The results of this survey show that subsequent to the completion of the IDP, students believed that valuable insight towards real-world practises were obtained and basic project management skills were developed. Moreover, it appeared that the overall enthusiasm respondents had towards the course perpetuated throughout the IDP with the majority of respondents indicating that they would like to see similar projects in the future.

6.0 Conclusions and Recommendations

Based on student responses, the pivotal objectives for the IDP were achieved. One motivation was to show the value that each of the courses had to offer to the amalgamated whole through the integrated project. Student feedback indicated that approximately half of the survey respondents felt more engaged in the individual courses due to their specific importance within the design process. The IDP allowed for students to observe the connection between what they are taught in the classroom to how this knowledge can serve as a resource to them in solving real world problems. Another motivation was to demonstrate the value of teamwork and highlight the benefits of collaboration with others. Survey results indicated that the majority of respondents wanted to work as a team prior to the start of the IDP and the majority indicated that they enjoyed working as a team in the post-project survey.

Clearly defined scheduling requirements are recommended to combat time management issues reported by survey respondents. Implementing scheduling requirements would inadvertently improve communication between group members and project management aspects of the IDP. This may also assist students in appropriately scheduling their progression on the IDP throughout the term, discouraging procrastination. As part of this scheduling component, students may directly assign roles such as project manager, lead designer, head contractor, etc., further establishing individual responsibilities within the group environment. It is also recommended for future projects to include an emphasis on report writing and formatting. Since a written report is one of the primary deliverables, it would be valuable to demonstrate to students the importance of a clear and professional presentation of technical information.

Instructors in UW's Civil Engineering program are largely impressed with the outcomes and successes of the IDP. However, several challenges were faced and must be addressed for future years. One of the primary challenges faced was the curriculum change where Engineering Economics was replaced with Transportation Principles and Applications. The curriculum change rendered the project description used in 2015 incapable of integrating the knowledge learned in the new course. Therefore, the instructors revised the project definition to accommodate the new course included in the second year curriculum by changing the proposed bridge location from a crossing with horizontal approaches and a well-defined clear span distance to a flood plain scenario with sloping approaches on either side and a variable clear span distance. Curriculum changes are not frequent and are not a challenge anticipated to occur in the next few years.

Conversely, a challenge likely to occur more frequently is the change of instructors for a particular course from year to year. Gaining the interest of new instructors and updating them on the project requirements proved to be a significant challenge. This could be resolved by the department including the IDP as a compulsory project within the second year curriculum. Alternatively, if over time the IDP appeals to enough of the professors within the department, then perhaps the inclusion of the IDP will occur naturally.

Moreover, it is recommended to establish an elevated level of communication amongst the instructors for all integrated courses to optimize the execution of the IDP, minimizing the conflicts and maximizing the value to the students. It is recommended to plan for the IDP well in advance (e.g., in the preceding term). This is to combat the challenge involving the communication and scheduling difficulties between the four instructors. A viable solution may be to arrange a timeslot where all of the instructors are in one room in front of the students to present and describe the particulars of the IDP, invoking their enthusiasm and allowing for questions to be answered with the input from all instructors. Presenting the IDP to the students with all the pertinent instructors in the room was found to be especially beneficial in 2015, specifically for increasing the motivation and understanding of the students towards the relevance of the IDP to the real world.

References

Anderson, L., Krathwohl, D., & Bloom, B. (2001). *A taxonomy for learning, teaching, and assessing : A revision of Bloom's taxonomy of educational objectives* (Complete ed.). New York: Longman.

Barragán, E. I., Mercado, A., & De Hoyos, G. (2005). Horizontal integration in teaching within a biomedical department. *Medical education*, *39*(11), 1148-1149.

Barrella, E., & Watson, M. K. (2015). Comparing the outcomes of horizontal and vertical integration of sustainability content into engineering curricula using concept maps. International Conference on Engineering Education for Sustainable Development (EESD) (7th : 2015). C, . Retrieved January 25, 2017, fromhttps://open.library.ubc.ca/cIRcle/collections/52657/items /1.0064682

Bloom, B. (1956). *Taxonomy of educational objectives : The classification of educational goals*. New York: Longman.

Figueiredo J. (2017). Learning Engineering Through Teams. In: Auer M., Guralnick D., Uhomoibhi J. (eds) Interactive Collaborative Learning. ICL 2016. Advances in Intelligent Systems and Computing, vol 544. Springer, Cham

Gary, K. (2015). Project-Based Learning. *Computer, 48*(9), 98-100.

Giralt, F., Herrero, J., Grau, F. X., Alabart, J. R., & Medir, M. (2000). Two way integration of engineering education through a design project. *Journal of Engineering Education*, (April), 219.

Hassan, S. (2013). Concepts of vertical and horizontal integration as an approach to integrated curriculum. *Education in Medicine Journal*, 5, 5.

Heer, R. (2012). A model of learning objectives. *Centre for Excellence in Learning and Teaching, Iowa State University.*

Knight, D. W., Carlson, L. E., & Sullivan, J. J. (2007). Improving Engineering Student Retention through Hands-On, Team Based, First-Year Design Projects. *31st International Conference on Research in Engineering Education*.

Noordin, M. K., Nasir, A. N., Ali, D. F., & Nordin, M. S. (2011). Problem-Based Learning (PBL) and Project-Based Learning (PjBL) in engineering education: a comparison. *Proceedings of the IETEC*, *11*.

Orkwis, P. D., Walker, B. K., Jeng, S. M., Khosla, P. K., Slater, G. L., & Simitses, G. J. (1997). Horizontal and vertical integration of design: an approach to curriculum revision. *International Journal of Engineering Education*, *13*, 220-226.

Snyman, W. D., & Kroon, J. (2005). Vertical and horizontal integration of knowledge and skills- a working model. *European Journal of Dental Education*, *9*, 26.