Student Engagement In Capstone Projects Through Integration of Technologies, Project Assessment and Academic Integrity

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ABSTRACT

Many technology students face challenges when it comes to executing assigned objectives in their team-based capstone projects. Problems in implementation can be due to a lack in project planning experience and the related issues involved with student confidence in light of inexperience, difficulties appreciating the many requirements involved with applied learning, including the practical skills involved, issues with developing strong team communications, or problems securing resources to bring projects to fruition. The paper will briefly present the Canadian accreditation process for technology programs and the authors' experiences in conducting and assessing a capstone course over its five year developmental span. The paper will also elaborate on the processes that enable simplification of the many elements to project development, including the establishment of effective communications and technical reporting, the process of task assignment to team members, the use of evaluative tools within the online context of the college's learning management system, and how students solve problems and manage time commitments throughout their learning process. The paper will provide a sample of the processes and assessment tools used in Lambton College's School of Technology, which awards students an advanced technology diploma degree

Keywords: Integration of Technologies, Project Assessments, Capstone Projects, Academic Integrity.

1. Canadian Universities and Colleges Accreditations System

Accredited engineering programs ensure that programs are meeting the high standards that are accepted by engineering regulators nationwide and are also recognized by international partners. Many international institutions use the *Accreditation Board for Engineering and Technology* (ABET) criteria as a guideline in developing the intended learning outcomes for the offered engineering and technology programs [1]. The process for accrediting an engineering program is undertaken by the Canadian Engineering Accreditation Board (CEAB), a working Board of Engineers Canada (EC). There are currently 279 accredited engineering programs at 44 higher institutions across Canada in a wide range of engineering disciplines[2]. The process of accreditation in technology studies in colleges is undertaken by the Canadian Technology Accreditation Board (CTAB) [3]. The CTAB is a standing committee of the Canadian Council of Technicians and Technologists (CCTT). CTAB is charged with developing, coordinating and managing the national accreditation program for applied science and engineering technology programs. CCTT, in partnership with the National Council of Deans of Technology (NCDoT) and the Council of Registrars (COR), developed new outcome-based criteria for national accreditation and certification in Canada. The National Technology Benchmarks - NTB® (NTB) have been accepted by the Association of Community Colleges (ACCC), which is now renamed the Colleges and Institutes Canada (CICan) [4] for the benefit of all educational agencies in Canada.

Not only is there a huge interest in capstone project courses at the under-graduate level of engineering studies, but also in technology diploma-offered degrees. Capstone themes span wide areas of interest including engineering design, manufacturing, system engineering and software development, project management, automation, and aerospace programs [5], [6]. Successful implementation of capstone courses within accredited programs can result in a number of significant benefits for the academic institutions, the students, and involved businesses.

1.1 The WIL

Work Integrated Learning (WIL) [7] is a fundamental part of the Canadian undergraduate experience and is one of several commitments made by the Canadian Business/Higher Education organization representing some of Canada's leading companies and post-secondary institutions. WIL is an umbrella term for partnerships between colleges and employers. WIL combines learning with practical experience. The opportunity to execute WIL in colleges might not be a straight forward task and there are questions concerning whether or not a capstone project experience can provide the necessary platform for connecting classroom learning with workforce requirements in order to meet WIL expectations. There are various designed curriculum and assessment tools for universities' and technical colleges' engineering and technologies programs, and these are successfully implemented in many institutions worldwide, meeting accreditation organization guidelines. In some cases, capstone projects are executed in a virtual product development environment [8]. The common conclusion is that each capstone course needs to be tailored to meet the respective program's

intended learning outcomes and must keep in mind the needs of local businesses for skilled graduates.

1.2 Lambton College

Lambton College is one of the smallest colleges in the province of Ontario, Canada. Its technology program's co-op placement ratio meets the provincial average and beyond. An accredited program in Instrumentation Engineering Technology (IET) is designed to prepare graduates with the technical skills necessary to enter careers in design, manufacturing, marketing, operations, and maintenance in the fields of measurement and control engineering technology. One of the IET occupational outcomes requires the program graduate to:

1. Use project-management software tools in the development of an engineering project.
2. Reference and interpret source documents from manufacturers and suppliers to obtain information required to select and purchase appropriate equipment, components, and systems.
3. Determine the functional specifications of equipment, components, and systems.
4. Select electronic equipment, components and systems by consulting manufacturers' specifications, catalogues, and electronic sources, such as the Internet and/or CD-ROMs.
5. Design and develop a Safety Instrumented System and a Hazardous Operability Analysis for a project.
6. Prepare requisite engineering drawings and supporting documentation.
7. Understand the principles of Project Management, including related software.
8. Apply industry codes and standards, including occupational health and safety, in a project's design and implementation.
9. Apply the principles of team building in an engineering project.
10. Apply established codes of professional ethics.
11. Interpret and apply environmental regulations and practices.

Successful execution of program outcomes will ensure students are well-prepared for the work environment, and the capstone project component ensures the accreditation of the IET program. Since 2013, the Instrumentation and Control Engineering Technology (ICET) program at Lambton College has been leading the way in integrating the capstone project in its three year co-op program.

1.3 Lambton College ICET Program

At Lambton College School of Technology, the ICET program is a three-years plus three-term co-op technology IET program. Enrolled students are trained in state-of-practice technology laboratories and with an infrastructure that supports learning and research using next-generation technologies in collaboration with industry. Laboratories are designed to foster hands-on learning, allowing for equipment installations, configurations, calibrations and troubleshooting. Students maintain instruments (pneumatic, analog, and digital) and control systems in a variety of industrial-replicated settings. After the fourth term (two academic years) of classroom and laboratory studies, students compete for an eight month co-op term in manufacturing industries and engineering firms. Students return for a fifth term of schooling. Students then compete for a third term of co-op. Finally, students complete their sixth and final term of studies where their capstone project is one of the main courses. Successful graduates of the program are eligible to receive credit for all three levels of Ontario's Instrumentation and Control Technician (447A) in-school apprenticeship training.

2. THE MAIN CHALLENGES OF PROJECT IMPLEMENTATION

There are several external and internal challenges to consider before the capstone project curriculum is successfully integrated into the larger ICET program. To begin, organizers must acknowledge that the college's internal financial resources might not be sufficient to cover the costs of capstone-related supplies and activities. There are external economic factors to consider as well: as the economy fluctuates, an employer, as a potential partner in the development of a capstone project, may be compromised financially and will therefore be unable to afford the cost of hiring students.

Compared to university-level capstone courses, which are more heavily complemented with mathematical and analytical research, college capstone courses orient more to the applied aspect of science and technology. Within this context, the first step in the development of the ICET capstone project course must be to simplify the engineering research and development cycle to be suitable to student learning in the college environment.

A college-level capstone course begins by identifying the targeted challenges, searching and assessing solutions, designing and building prototypes, and then validating and refining the designs to ensure that the problems are addressed as expected. This might very well be the needed experience required by technology firms. Given the time-frame of one to two academic terms that college-level capstone projects demand, and given also that students might be burdened with other challenging courses while developing their capstone projects, students must be skilled at balancing time commitments and conflicting demands.

In order to implement and complete the capstone project components effectively with time restrictions and under performance expectations, the students will also need strong academic habits, including work ethic, independence, effective communication skills, social responsibility and the capacity to work well as a part of a team.

Therefore, well-designed learning processes must be a part of the course design and supervisory considerations in order to support such habits. All capstone processes should include clear directions on how to start and to complete the project phases, how to establish lines of communication, how to build effective teams, how to manage conflict and how to ensure academic integrity is an integral part of each step of the learning process.

3. THE ENGAGEMENT PROCESS

In order for the capstone projects to each effectively evolve, the involved program faculty, the students, and in some cases, the industrial partners, must collectively establish agreed-upon capstone themes and suitable objectives prior to the start of the academic term. In the ICET experience, early capstone projects targeted the recycling and reuse of manufacturing systems components. Many employers responded quickly to the call for components and forwarded their abandoned units for recycling purposes. The intention for the program was to reuse some components to build additional prototypical laboratory equipment in order to support other college technology course's training facilities. After the first delivery of capstone projects, the College's applied research activities drew significant amounts of applied research funds and began attracting a wider participation of employers. Integrating applied research with capstone project themes and ideas offered a great opportunity to involve students in a modelled work environment. As the applied research funds began to flow, the projects aimed to support the needs of research partners in developing needed products for their use. As a result, the ICET capstone course achieved WIL requirements and exceeded initial expectations for this environment.

4. THE CAPSTONE PROJECT'S GUIDING STATEMENTS AND PROCESSES

In order to direct students through each of the different stages of a capstone project's life cycle, a few guidelines are important to establish. Each term, once students are prepared to face potential project challenges and to work safely, they must decide on their projects. Team selection is important and the process is jointly accomplished with input from the involved faculty member and the students. There is a student nomination process for deciding which of the teams will execute which of the capstone projects. Once projects are decided upon, teams begin to work on their project statements and to execute a draft of their plan with a bird's eye view of project activities.

Each team establishes channels of communication and begins by outlining their responsibilities in the group. Teams conceptualize their projects' main components and must describe the proposed designs for each of the various milestones at each stage of project development. For each project, teams conduct risk assessments and mitigation. Students also participate in organizing and purchasing components within their allocated budgets, and will follow up by communicating progress on their project's proposed main deliverables at each stage. Teams use a project activity progress tracking sheet to demarcate their project's progress and an example of a completed tracking sheet is circulated beforehand so students may know how their work is to be done. A sample of a completed document used to track progress is shown in table (1).

A technical documentation progress sheet for each project is also required of the teams. Each project's progress sheet must include a technical design of the project, project drawings, the operational procedures, their budgets, and any bills for purchased materials.

An example of a completed project technical documentation progress sheet is likewise circulated among students to ensure each team is knowledgeable of the requirements for a well-documented project.

5. THE ASSESSMENT PROCESS

Capstone projects present many challenges for effective assessment, as compared to traditional academic technology courses, where there is well-defined structure in course outlines, laboratory manuals and associated assignments. Because of the involved challenges to assessment, both direct and indirect assessments are used throughout the project process in order to monitor progress and reflect fair judgment on student performance [10] [11]. Rubrics are one of the main guiding tools for capstone project assessments, [12] involving both systematics and quantitative evaluation processes. In ICET capstone project assessments, rubrics are used at each stage to provide feedback on progress and to identify and investigate qualities inherent to the students' group work activities. A sample rubric is shown in table (2). The College's on-line learning management system, as well as Google Drive is used to communicate rubrics, to assess the students in their progress, and to provide a forum to collectively discuss projects' ongoing challenges.

6. THE ACADEMIC INTEGRITY, WORKLOAD SHARING AND FAIR ACKNOWLEDGMENT OF EFFORTS

The goal for any successfully developed capstone project is the application of technical abilities together with the demonstration of a comprehensive set of professional skills. Time management, organizational skills, peer leadership and teamwork are all demanded implicitly from students in their capacity to successfully work through the stages of capstone development.

Integrity or ethical behaviours are also intrinsic to success with a capstone-learning environment. Often ethical behaviours in the academic environment are perceived only as the absence of academic dishonesty, where success is defined by a lack of evidence for any act of explicit disregard for the values of individual representation, honesty, and fairness. However, in the circumstances of a capstone learning environment, ethics or academic integrity is expressed by directly observed and measurable positive behaviour, as defined by in-context prosocial behaviours in group work, proven competence in skills and knowledge, and effective communication. Rather than by the absence of negative academic behaviours found with cheating, ethics in the context of capstone learning is an expression of the positive results of values-based learning: accountability, pro-social responsibility and consistency in effort throughout the stages of capstone development. Students who have not established the behavioural proficiencies involved with values-based accountable learning in their courses leading to the capstone project will be burdened with greater learning demands during the implementation stages of the capstone project and in the project's subsequent workload and expected team-based dynamics. Therefore, to meet these concerns, and to prepare students for such expectations, directives on what is required professionally and in academic conduct must be a regular part of instruction for the students in the program.

These directives in professionalism and academic conduct include defined standards of academic integrity, defined measures of suitably expressed in-context ethical behaviours, and defined in-context prosocial team-based behaviours. With pervasive and consistent instruction throughout their program, students may adopt these behavioural standards into their regular academic habits as pervasive program social norms. While

involved in the capstone project experience, students must continue to articulate ethical conduct and prosocial behaviours with expectations of accountability in their work. Students are expected to disseminate their projects' workloads fairly, to demonstrate responsible team membership in both consistent attendance and responsibility in their individual roles. Students are also expected to demonstrate prosocial conduct by effectively articulating productivity and their workings towards milestones in their groups' reporting, as well as through the evolution of team communication habits more generally. Team members, as an inherent part of working together to demonstrate these communication expectations, will often speak to challenges in group dynamics; for example, in fair distribution of work or with interpersonal conflict.

The result of these reporting measures is the establishment of an evidence-based system of information exchange that represents the nature of the team dynamic and the problem-solving qualities of the group. Faculty leadership must ensure there is consistency in student communications so to clearly develop and demonstrate each team members' work ethic, participation, and nature to the group dynamic throughout each stage of project development.

Concerns in both interpersonal developments or in technical challenges must be addressed openly and professionally by both the student team members and the faculty lead as a part of the assessment process. With reporting transparencies and the encouragement of an open process of team problem-solving, students become familiar with the ethical nature of effective communication in this context.

7. CONCLUSION

The potential for student learning within the context of capstone project development is significant. A capstone learning context permits the realization of integrating classroom learning with practical hands-on experience that more closely represents workforce requirements.

Applied team-based learning projects require students to demonstrate their developed technical skills, their levels of professionalism, and their communication skills, as well as confront the many ethical challenges involved with this multifarious learning context. With such potential as a learning context in an academic setting, the challenges inherent to its development, although many, are worth confronting. With five years of experience as a leader in capstone project implementation, the Lambton College ICET program has achieved measurable success through its student engagement aims.

There are several facets of resources required to achieve this necessary context, including external and internal as well as material and facilitative resources. However, with clearly defined procedures, comprehensive assessments and process-based faculty supervision, as articulated in detail with the qualitative analysis associated with this paper, students can demonstrably achieve important real-world learning outcomes with applied learning strategies.

TABLE (1) Capstone Project Activities Check List

Note 1: The following table would provide you and your team members a list of activities that carried out during the life span of the project.

- You need to check the list every week and fill-in the information periodically.
- Store any supporting documentation until the final submission.

Note2: Remember, the minimum project deliverables are:
1- Complete detailed technical documentation, including drawings and any testing and commissioning procedures.
2- Working prototype in a safe manner in accordance with the code.
3- Technical presentation using presentation media software.

Dynamic Check List of Activities	Comments
❒ Identified team members	List the names:
❒ Nominated team leader	Name:
❒ Selected/nominated a project idea	Title:
❒ Done background research on the project idea	Findings:
❒ Confirmed projects deliverables	List of deliverables:
❒ Defined the major tasks/activities need to be addressed	You must reference to the list of task and who do what. Comment on changes.
❒ Specified project requirements	Keep track of all the project requirements and any changes.
❒ Specified project location	Specify where the work will be done.
❒ Carrying out continuous brainstorm solutions	Must meet every week and record the minutes of meetings.

8. REFERENCES

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	TABLE (2) Capstone Project Evaluation Form				
	(100 - 75) %	**(75 - 50) %**	**(50 - 25) %**	**(25 - 0) %**	**Grade**
1. Project Overview (10 %)	Clearly described the project objectives and expected deliverables	Somewhat described the project objectives and expected deliverables	Hardly described the project objectives and no expected deliverables	No description of objectives nor expected deliverables	
2. Detailed Scope (20 %)	Detailed specific scope of what is needed to be done, resources, listed tasks and who is doing what	Somewhat specified what is needed to be done, resources, listed tasks and who is doing what	Very little information on what is needed, resources, listed tasks and who is doing what	No information on what is needed to be done, resources, tasks and who is doing what	
3. Project Schedule (20 %)	Provided detailed project stages, timetable, completion dates including expected milestones and constraints	Somewhat provided some project stages, timetable, completion dates including expected milestones and constraints	Hardly any time horizon of the project stages , or expected completion dates nor milestones and constraints	No information on project stages, completion dates nor expected milestones and constraints	
4. Project Budget (20 %)	Provided detailed bill of material, showed budget is based on quotes, included contingency component, delivery milestones and constraints	Provided incomplete bill of material, showed budget is based on quotes, included contingency component, delivery milestones and constraints	Hardly any detailed bill of material, budget, did not show any quotes nor any contingency component nor delivery milestones and constraints	No clear information, unacceptable format and/or illogical budget	
5. PROJECT Documentation including Instrumentation & Control drawings and any supporting documents (30 %)	Provided documentation following applicable standards that included P&ID, DCS & marshalling panels, electrical or mechanical drawings with clear instructions	Some documentation was presented following applicable standards that included P&ID, DCS & marshalling panels, electrical or mechanical drawings with clear instructions	Hardly any documentation presented and lacking standards and missing P&ID, DCS & marshalling panels, electrical, mechanical drawings nor instructions	No documentation that can be accepted	