Multidisciplinary, Vertically Integrated, and Community-Based: A New Approach to Engineering Education

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# Table of Contents

**Motivation** .................................................................................................................. 3  
Educational Reform ............................................................................................................. 3  
Graduate Attributes ........................................................................................................... 3  

**Solution** ....................................................................................................................... 4  
Graduate Attribute Analysis ................................................................................................. 5  
  A knowledge base for engineering .................................................................................... 5  
  Problem analysis ................................................................................................................. 5  
  Investigation ...................................................................................................................... 5  
  Design ................................................................................................................................. 5  
  Use of engineering tools .................................................................................................... 6  
  Individual and team work ................................................................................................. 6  
  Communication skills ...................................................................................................... 6  
  Professionalism ................................................................................................................ 6  
  Impact of engineering on society and the environment ................................................... 6  
  Ethics and equity ............................................................................................................... 7  
  Economics and project management ............................................................................... 7  
  Life-long learning ............................................................................................................ 7  
  Sustainability .................................................................................................................... 8  
Vertical Integration ............................................................................................................. 8  
Service Learning ................................................................................................................ 9  
Design Education ............................................................................................................... 10  
Reflection ............................................................................................................................ 12  
Multidisciplinary ............................................................................................................... 13  

**EPICS: Engineering Projects in Community Service** ......................................................... 14  
Key Features ....................................................................................................................... 14  
  Community Partners ....................................................................................................... 14  
  Large, Vertically-Integrated Teams ................................................................................ 15  
  Long-Term Student Participation .................................................................................... 15  
  Variable Credit Hours ..................................................................................................... 15  
  Multidisciplinary Teams ................................................................................................. 15  
  Start-To-Finish Design Experience ............................................................................... 15  
Learning Outcomes ........................................................................................................... 16  
Women in Engineering ....................................................................................................... 16  
Student Retention ............................................................................................................. 17  
Alumni Engagement ......................................................................................................... 18  

**Implementation** .......................................................................................................... 19  
Staff ...................................................................................................................................... 19  
Funding Options ................................................................................................................ 19  
  The JW McConnell Family Foundation ........................................................................... 19  
  Other Options .................................................................................................................. 20  
Learning Portfolio .............................................................................................................. 20  
Short Term .......................................................................................................................... 21  
Long Term .......................................................................................................................... 21  

**Works Cited** .................................................................................................................. 23
Motivation

Undergraduate students in engineering are entering a new generation of expectations for engineers. They face a future in which they will need more than a solid technical background to be successful [1]. Engineers are now expected to be competent in a greater range of proficiencies, and be able to interact effectively with people of widely varying social and educational backgrounds. They must be proficient problem solvers, with a skill set required to not only interpret the available data, but also design experiments and solutions using the appropriate set of tools. Engineers must have an understanding of the roles and responsibilities of professional engineers, as well as the ability to analyze their impact on society and the environment.

Educational Reform

Among the most dramatic statements regarding the importance of these skills are the set of desired educational outcomes, or “Graduate Attributes”, that now form the backbone of engineering accreditation guidelines in Canada [2]. In addition to knowledge in engineering, mathematics, and science, these criteria call for students to be able to analyze and solve complex engineering problems and to communicate effectively in a multi-disciplinary setting. They also call for students to be able to apply professional ethics, and understand the importance of societal and global impacts imbedded throughout engineering solutions [1].

Graduate Attributes

According to the 2012 Canadian Engineering Accreditation Board Accreditation Procedures, education institutions must demonstrate that the graduates of a program possess the attributes under the following headings [2]:

- **A knowledge base for engineering**: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.
- **Problem analysis**: An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.
- **Investigation**: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.
- **Design**: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.
- **Use of engineering tools**: An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.
**Individual and teamwork**: An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.

**Communication skills**: An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.

**Professionalism**: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.

**Impact of engineering on society and the environment**: An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.

**Ethics and equity**: An ability to apply professional ethics, accountability, and equity.

**Economics and project management**: An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.

**Life-long learning**: An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge [2].

**Solution**

One effective solution to these criteria is a curriculum or program that engages students in ‘real-world’ experiences. Proper design of these experiences is a delicate process; they must offer students a compelling context for technical engineering design, multi-disciplinary team experience, and an opportunity to practice professional skills, while also being compatible with an engineering curriculum and cost-effective for the faculty. Appropriate implementation will ensure that students can immerse themselves in the engineering experience, thus learning the desired skills and addressing the corresponding attributes as they design their solutions [1].

A program such as iMMERSE provides students with a supplementary option to gain real-world experience solving a technical-based problem. More importantly, it provides a forum for McMaster engineers to develop the Graduate Attributes – many of which are difficult to incorporate into engineering curricula due to the model on which much of the current traditional educational practices are based [3].

While educators are consistently seeking to provide the best learning experiences to students, local organizations are searching for someone who can
improve the technology they require to service the community [1]. Community service agencies, educational institutions, museums, and local government offices all face a future where a lack in modern technologies will be detrimental to the services they offer. They often possess neither the expertise nor the budget to obtain or create an appropriate solution to their problems [1]. Engineering students are willing, capable, and an extremely economic solution to these issues.

**Graduate Attribute Analysis**

This program also serves as a tool for faculty administration to demonstrate that graduates indeed possess certain Graduate Attributes, which again, most of which would otherwise be extremely difficult to validate. The program’s benefits with respect to each Graduate Attributes are explained below:

**A knowledge base for engineering**

iMERSE provides students with an opportunity to demonstrate their understanding of engineering knowledge. They solve technical problems that require the use of said knowledge, and are able to fabricate tangible showpieces of their knowledge in the form of practical solutions. Additionally, iMERSE allows students to develop the skills necessary for industry that are never taught or utilized in the classroom setting (ex. Excel Macros). It also gives students the opportunity to master skills that are touched on in the undergraduate curriculum but are crucial to succeeding in industry (ex. Matlab).

**Problem analysis**

iMERSE gives students experience actually solving real-world problems, something rarely offered in the traditional classroom setting. Students get experience exploring what is, and what is not, critical information to problem definition. They can develop their ability to reach substantiated solutions, as well as demonstrate their ability to identify and analyze complex engineering problems.

**Investigation**

iMERSE gives students the chance to investigate a complex problem and develop an appropriate plan of action. They must pick suitable experiments on their own, without a lab manual, combined with an iterative design process to fulfill their goals. The iterative design process forces them to interpret and synthesize open-ended data from their tests in order to further develop their design.

**Design**

This Graduate Attribute is the essence of iMERSE. The program’s fundamental goal is to provide students with an opportunity to develop and practice design skills. The program will test their ability to design solutions for complex, open-ended engineering problems while paying attention to economic, environmental, and societal considerations. They will also be able to demonstrate their efforts and capacities through a feasible solution that can be deployed to meet the needs of the key stakeholder.
Use of engineering tools

iMMERSE gives students an opportunity to both develop and demonstrate skills in their engineering toolbox. In order to solve the specific problem, they will first have to select different methods of solving the problem, such as two different paradigms of programming languages. They will have to consider the situations where one may flourish over another, and understand the associated limitations of each. They must be able to adapt the tool appropriately, and then apply their knowledge to engineering application, both safely and effectively.

Individual and team work

This program accommodates one of the only opportunities where McMaster engineering students get to work in vertically integrated teams. It is also one of the few programs/courses that allow students to work together in a multi-disciplinary setting. Additionally, the program gives students experience working both in team and individual environments, depending on the stage of the project. It allows them to take on different roles within the project, starting as a general member and potentially evolving into team lead.

Communication skills

iMMERSE puts students in charge of their own development when it comes to communication skills. They must become competent in reading and writing technical reports, communicating within the team by giving and taking instructions, and they must be able to present their solution effectively to the community partner. Most importantly, in order to succeed they must come to understand the value of complete problem definition, which stems from substantial communication with the partner. The first stage of the project after the team has been assembled is the project proposal; the team will meet several times with the project partner to define the project and determine its goals. During this phase, the project team learns about the mission, needs, and priorities of the project partner. Even after the proposal has been accepted, regular interaction with the project partner continues in order to ensure that the products being designed are developed as desired. From written progress reports to formal presentations, communication is crucial to bringing value to all parties involved, and iMMERSE provides an unparalleled experience.

Professionalism

Engineering students in iMMERSE get first hand experience managing a real-world project from the perspective of a project engineer. The experience starts with communicating with the client to understand the needs of the stakeholder, and ends with delivering them a product of value. Throughout the project’s timeline, the students will experience the roles and responsibilities of the professional engineer in society. Most importantly, they will face certain scenarios causing them to realize the power of engineering errors, thereby teaching them the significance of the role engineers serve in protection of the public.

Impact of engineering on society and the environment

When completing the project, the students will come to appreciate the
importance of moral engineering. Through decisions they make and people they meet, they will get first hand experience understanding the interactions engineering has with the triple bottom line. IMMERSE also gives students an opportunity to demonstrate their comprehension of the value of the triple bottom line, something that is often difficult in the traditional classroom setting.

Ethics and equity

IMMERSE provides students a chance to venture out of the classroom and be truly accountable for their actions in a real-world scenario. They will develop and eventually demonstrate their understanding of ethics, and their ability to follow through on deliverables and deadlines.

Economics and project management

IMMERSE gives students the ultimate project management experience. They are self-driven, working on a student-run team, in order to design a practical solution to a real issue in society. The first step is assembling a team that can fit the project’s needs. They can choose from a variety of engineering departments as well as non-engineering disciplines. The teams are comprised of a mix of all years; teams need technically advanced members (usually upper years) and students in lower years to learn about the project and ensure continuity. If projects last many years the younger students will have the opportunity to take on more leadership roles within the team. After the team is assembled and the project proposal has been approved, the team members must address administrative matters, do project tracking and planning, and work on the technical aspects of their project. Students also get experience in working with clients and other stakeholders to develop products and services that meet the needs of everyone involved. They must work within their budget, but also make sure that the solution is economically feasible for the clients and within all fixed constraints. Capstone projects are currently one of the only curricular project management experiences offered, but it lacks many real-world project characteristics. IMMERSE is an ideal experience for project management and provides a variety of different benefits over the final year capstones, such as vertical integration, multidisciplinary teams, and multiple year projects.

Life-long learning

Programs similar to IMMERSE that contain self-directed learning excite students about education. It allows students to work on a project that they are passionate about. A very similar program to IMMERSE, EPICS at Purdue University, conducted a written survey that included a free response question. Representative comments include: “Working on this project has helped me guide the rest of my coursework and ideas for a future profession” and “No longer is engineering just a bunch of equations, now I see it as a means to help mankind”. EPICS alumni have become the community partners for current projects, and an alumnus also created an EPICS High School program. Additionally, alumni created a scholarship for students involved in EPICS, and an alumnus who won the ECE Alumni Design Award cited EPICS as “having the most influence on his development as a design engineer”
Both the EPICS students and alumni clearly see the importance of the unique program. This real world, project-based learning, gives students the confidence to continue self-directing their growth, and ultimately promotes the value of knowledge.

**Sustainability**

The term sustainability includes three dimensions: environmental, economic, and social. Due to the culture of McMaster Engineering, iMMERSE will most likely include a triple bottom line analysis of their final solution. Students will have to think about the planet, the profit, and the people throughout the duration of their design process to ensure that it is sustainable. The environmental analysis would include how the design benefits the client and society as much as possible while minimizing environmental impact. The economic evaluation will analyze the impact the design has on its economic environment of the host society. The social aspect would examine ethical issues, from user safety all the way to child labour exploitation during the procurement of materials. Socially speaking, it also promotes sustainability by facilitating the sharing of knowledge and expertise between different economic and educational classes. The triple bottom line analysis of their design will not only develop the ethical mindset, but also demonstrate that they are able to design solutions with sustainability as a priority.

**Vertical Integration**

Vertical integration (or inter-year collaboration) allows students from across the spectrum of experience, from first year to final year, to work together on the same project. It allows students to learn not only from others, but also by solidifying concepts through teaching. Conceptual and philosophical reinforcement of technical knowledge is supported in addition to the students improving their leadership and team building skills [4].

The upper year students become mentors and have an opportunity to develop their ability to communicate with someone on a less technical level; this improves their practical communication skills for when they work with clients in industry. The lower year students get to learn from older students, gaining experience with more complex problems and usually the chance to work on a more open-ended design scenario than their traditional curriculum provides. They also get improved communication skills and the chance to expand their technical vocabulary. Vertical integration creates an environment that promotes teaching and learning between all years. It increases the individual students’ networks and as a whole it fosters a greater sense of collegiality within the departments and faculties involved.

From the Faculty's perspective, apart from the improved education, vertical integration also brings various administrative benefits. If the structure facilitates all levels to be in in concurrent lab sections, it is a more efficient use of equipment and facilities. It promotes multi-purpose facilities as opposed to the current practice
that devotes specific labs for certain levels, and, in some cases, even certain courses. Moreover, if the older students spend time teaching the lower years, it can become a more effective utilization of faculty's time [4].

**Service Learning**

Service learning is a form of experiential education in which students apply the knowledge they learn in the classroom to carry out projects that meet local community needs [5]. It engages students in opportunities intentionally designed to promote student learning and development; reflection and reciprocity are two key concepts [6]. The goal of reflection is to promote learning about the larger social issues behind the needs to which they are servicing. This includes deeper understanding of the historical, sociological, cultural, economic, and political contexts of the issues being addressed [6]. The reciprocity pillar ensures the students’ projects are defined by the needs of the community as opposed to being based solely on the desired student learning outcomes, providing services that do not meet actual requirements. Through reciprocity, students develop a greater sense of belonging and responsibility as members of their community [6].

In 2012, the Canadian Engineering Accreditation Board (CEAB) formalized the incorporation of ‘softer’ skills into the undergraduate curriculum. This paradigm shift will first be tested in 2015, when engineering schools must demonstrate that in addition to the technical knowledge, their graduates also are competent in the specific Graduate Attributes. These ‘soft’, or professional, skills include attributes such as: leadership and teamwork skills, professionalism, communication skills, understanding one’s impact on the triple bottom line, project managements skills, and using ethical behaviour.

Leah Jamieson’s EPICS (Engineering Projects in Community Service) program at Purdue University uses service learning to implement a vertically integrated, multidisciplinary design course where students work together to solve community needs. Their partner’s include K-12 schools, a children’s hospital, a zoo, and community-service agencies. The majority of students cite the opportunity to obtain ‘practice, real-world experience in engineering design’ as their primary reason for participating in EPICS, however a significant number also identify the opportunity to do community service as a major factor. In a summative evaluation of the program, 153 students from 1996 to 1997 gave ‘ability to work in a team’ and ‘understanding the design process’ the highest scores of 3.54 and 3.45 out of 4.0, respectively. ‘Community awareness’ received an average rating of 3.2 and ‘communication skills’ received an average rating of 3.36 out of 4.0 [7].

In a study done at San Jose State University, researchers looked for evidence concerning the benefits of service learning in order to be able to push its inclusion in the curricular mainstream. This study presents evidence that university students manifest long-lasting academic benefits from participating in service learning. The academic records of 477 students who completed a lecture course with or without a
service-learning requirement were examined and compared in four types of upper year courses. Overall, students in the “service learning” sections earned grades that were 4.8% higher than those of the “non-service learning” students (3.28 vs. 3.13 on a 4-point scale). For activity courses, students in the “service learning” sections earned grades that were 4.1% higher than those of the “non-service learning” students (3.52 vs. 3.38). For the capstone/reflection course, students in the “service learning” sections earned grades that were 4.3% higher than those of the “non-service learning” students (3.12 vs. 2.99). For the practicum courses, students in the “service learning” sections earned grades that were marginally 2.4% higher than those of the “non-service learning” students (3.43 vs. 3.35). For the lecture courses, students in the “service learning” sections earned grades that were nearly identical to those of the “non-service learning” students (3.16 vs. 3.18, p=0.8792). Although the benefits are relatively modest, the results do provide some support for the hypothesis that service learning provides students with a firm foundation upon which they can build their education on [8].

Design Education

In contrast to engineering design, where the objective is a solution, design education is primarily focused on students and helping them understand and experience the process and methods of realizing a solution. The quality of the student-designed solution is often of secondary importance in the learning process. Engineering educators believe that students should be able to develop design specifications, establish objectives and criteria, generate alternatives, and then synthesize, analyze, construct, test, and evaluate their final product [9]. The CEAB requires that every engineer must develop the Design graduate attribute, and therefore must have the “ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs” [2].

A study done at the U.S. Air Force Academy in Colorado Springs, Colorado, U.S.A. examined the benefits of a problem-based learning environment in an undergraduate engineering curriculum. The first year course, ENGR 110-Introduction to Engineering, is a design course where freshmen students work in teams to solve problems integral to a mission to Mars. The problem includes getting to Mars, constructing a research site on Mars, and developing a renewable power source on Mars. In addition to traditional knowledge objectives, the courses focuses on higher order processes such as analyzing ill-defined problems, communicating via multiple media, exhibiting intellectual curiosity, and developing a rich conceptualization of engineering [10].

The course used a set of eight dimensions to delineate the instructional design of ENGR 110, with each dimension defined as a bipolar continuum of values for a single pedagogical factor. “Goal Orientation” describes a range from highly specific (ex. applying mathematical formulas to calculate a specific value) to highly generable (ex. using a model to resolve a poorly defined engineering problem). “Pedagogical Environment” describes a range from instructivist (traditional lecture
based courses) to constructivist (where learners are responsible for their own learning). “Role of Instructor” describes a range from didactic (sage on the state) to facilitative (guide on the side). “Role of Technology” describes a dimension from surrogate instruction (something students learn from) to cognitive tool (something students learn with). “Nature of Learning Activities” describes a range from replication (memorization and practice problems) to generation (problem-solving and imagination). “Source of Motivation” describes a range from extrinsic (outside the learning environment) to intrinsic (integral to the learning environment). “Experiential Validity” describes a range from abstract (lectures and seminars) to concrete (hands-on projects and apprenticeships). The final dimension, “Collaborative Learning”, describes a range from proscribed (unnecessary to achievement in the course) to integral (necessary to achievement in the course). Using the eight dimensions, the differences between the ENGR11 and ENGR MECH 120 (a traditional lecture-based course) are illustrated below [10].

The Reflective Judgment Exercise (RJE) was administered to all ENGR 110 students as well as to the control group of ENGR MECH 120 students. An independent consultant from Reflective Judgment Associates scored all the RJE’s, using a procedure that kept her blind to the students’ membership in either ENGR 110 or ENGR MECH 120 courses. The instrument is scored using a 1 to 5 scale in which 1 represents deficient problem-solving, 2 represents D+ or S- scores, 3 represents satisfactory (S) results, 4 represents S+ or E- scores, and % represents excellent (E) problem-solving. The results can be seen below [10].
Students in ENGR 110 clearly developed an awareness of ill-defined problems within the context of engineering. The RJE provides evidence that the students also demonstrated improved capabilities to recognize problems as ill defined and use better approaches when solving them. The improvement on the RJE scores is both statistically and educationally significant, and a strong case can be made that the results stem from the unique learning environment of the ENGR 110 design course. This is especially true given the pedagogical dimensions of the course focused on problem solving. As illustrated in Figure 3, the findings represent a developmental shift from deficient to satisfactory regarding the students problem-solving skills. The students come to understand that engineering problems are complex and that there is often more than one right answer to any given problem. The success of the ENGR 110 course for resolving ill defined problems is exceptional, and similar design course structures should be considered for more engineering curricula. [10]

Reflection

Introducing reflection into engineering education provides the Faculty and student population with the opportunity to see what learning is occurring. By constructing reflective activities appropriately, Faculty members will be able to use reflection to identify which graduate attributes were completed in their course and could encourage students to further identify which activities specifically helped them increase their graduate attribute competencies. Additionally, reflective activities can be used to showcase these competencies to the Canadian Engineering Accreditation Board [11].

In terms of measuring the graduate attributes, this is where the reflective tools will come into play; by having students reflect on various aspects of their
engineering education, Faculty members will be able to extract pieces that demonstrate a sound understanding of certain graduate attributes that can be showcased. For example, a student could be asked to reflect on various components of their education such as communication skills, professionalism, and knowledge of sustainability [11].

Reflection encourages the growth of skills such as: problem-solving skills, higher order reasoning, integrative thinking, goal clarification, openness to new ideas, ability to adopt new perspectives, and systemic thinking [12]. These skills are reflected within the graduate attributes, and directly relate to problem analysis and lifelong learning specifically, but could be expanded to incorporate more of the attributes [11].

Lifelong learning is the attribute that is most difficult to quantify and demonstrate an understanding of, and how it contributes to life as a working professional. Consequently, it is the attribute that students have the most to gain from, as it a skill that will help them as the world evolves. By introducing reflective mediums into the curriculum, the notion of lifelong learning is quantified, with direct evidence to demonstrate that competency to the CEAB. Encouraging students to dive deeper into their education and examine how they can gather more information and guide them to be better learners will strengthen the concept of lifelong learning [11].

The learning portfolio is an excellent tool to bring together student work and reflection as well as reinforcing the importance of the graduate attributes. Encouraging students to confront their successes and failures and reflect on what can be done to enhance their learning journey will increase their comprehension of the graduate attributes, especially their understanding of lifelong learning [11].

**Multidisciplinary**

Graduates that are entering today’s integrated and cross-disciplinary workforce need to have developed not only the ability to work with those who are alike, but also those who are different. They must not be simply a “specialist” or a “generalist”, but be prepared to be a “totalist” [13]. Totalists can bring specialized skills, collaborate on projects, and overlap knowledge with other disciplines. Multidisciplinary education may be part of the solution to well-rounded engineers whom are competent in fields other than their own.

Professors at the University of Idaho School of Family and Consumer Sciences developed a “cross-disciplinary, experiential learning course” focussing on student-directed research studies [13]. Undergraduates, from sophomores to seniors, identified questions, designed studies, conducted research, and analyzed the results. The students were from a variety of fields and supported by an interdisciplinary team of faculty. To measure education philosophies, an achievement orientation survey was developed, splitting learning orientation into
“mastery”, the desire to engage in learning and ability to see the importance of developing new knowledge, and “performance”, the desire to outperform others and the aspiration for recognition over ability. Students who are mastery oriented tend to understand the value of teamwork, prefer changing tasks, enjoy their classes more, and see the correlation between effort and success [13]. The class average out of 5 on mastery and performance orientation was 4.73 and 2.5, respectively. Although the study contained no control group, the result still implies interdisciplinary projects with other departments and faculties can help significantly develop an appreciation for education, while promoting the important philosophy of collaboration over competition. Encouraging exposure to cross-disciplinary opportunities through experiential learning provides undergraduates with a greater understanding and appreciation of other disciplines and an ability to integrate that information into a variety of subject areas. They also have a highly developed ability to both identify as well as solve problems, and increased skills relating to teamwork, such as written and verbal communication [13].

EPICS: Engineering Projects in Community Service

Engineering Projects in Community Service (EPICS) is a program out of Purdue University that began in 1995 to fulfill the complementary needs of engineering undergraduates in the community. In this program, “undergraduates earn academic credit for their contributions to long-term, team-based design projects that deliver innovative, technology-based solutions to problems identified by not-for-profit organizations in the community” [1]. The unique structure and operation of EPICS allows solutions of significant benefit be delivered to the community. Key features of the EPICS model include the following attributes.

Key Features

While one or sometimes several of these attributes can be found in other programs, the special value comes when EPICS combines all of them. Included with the below descriptions are administrative examples of how EPICS is run at Purdue University. However, EPICS is operated slightly differently at every university that is a part of the EPICS University Consortium.

Community Partners

Each EPICS team is paired with a not-for-profit organization in the community that is referred to as the “project partner”. The team and its project partner work closely together to identify and solve the partner’s technology-based problems. The end result is the delivery and support of a system to be used by the partner that will improve either their infrastructure or services, thus improving the services the partner can provide the community. The partner’s suggestion of project ideas and feedback on the efficacy of current systems provides the real-world context for each EPICS project. An EPICS team’s design provides the project partner with real assistance, allowing the partner to better serve the community. The beneficial effects that the systems have on the community provide a compelling
reason for students to join and remain engaged throughout the lifetime of these projects [1].

**Large, Vertically-Integrated Teams**

EPICS teams consist of large numbers of students, usually around 4-15, thus enabling projects of significant scale and potential impact on the community to be undertaken. The large team size also allows for them to be vertically-integrated; that is, to contain all levels of students, from first years to seniors. In general, the seniors provide technical and organizational leadership, the second and third years perform the technical work organized by the seniors, and the first years learn about the project partner’s needs and participate in team tasks as much as possible [1].

**Long-Term Student Participation**

An EPICS student can participate in an EPICS team for multiple semesters, joining a team in the second semester of first year, remaining with the team until graduation. New first years or second years replace students that graduate or otherwise leave the team. Therefore there is significant continuity in team membership from semester to semester and year to year. When the continuity in membership is combined with proper team procedures for transitioning the new students as well as with appropriate mentoring by senior members and team advisors, the team’s effectiveness can be maintained for as long as required to complete a large-scale project. The continuity also provides each student with the experience and mentoring opportunities required to learn and practice different roles on the team, to trainee to design engineer to team leader [1].

**Variable Credit Hours**

An EPICS student earns one unit per semester as a first year or second year. As third or fourth years, they earn 1 or 2 units per semester, with the choice being made by the student each semester. The doubling of units available to the upper year students parallels their growing technical capabilities and organizational responsibilities. How the academic credit counts towards a student’s graduation requirements varies by department. For example, in ECE, up to 6 units may be used as technical elective credit, but in CE, only up to 3 units may be used as technical elective credit. Academic credit incorporation varies by department, faculty, and university [1].

**Multidisciplinary Teams**

The large team size enables students from disciplines across engineering and around the university to participate in EPICS. The disciplinary compositions of an EPICS team can thus be tuned to a specific project’s needs. For example, teams developing devices to assist children or adults with disabilities have drawn from such disciplines as electrical engineering, mechanical engineering, computer science, child development, and nursing [1].

**Start-To-Finish Design Experience**

Unlike most design courses, capstones included, EPICS provides a start-to-finish design experience for students. Each project begins with identification of the
project partner’s needs and the definition of a project to meet one or more of those needs. It then progresses through design, development, testing, and deployment, with the project partner. This process can often take two or more years, providing students with sufficient time to master many different aspects of an engineering design project. These aspects include: exploration of design alternatives, project planning and management, team leadership and transitioning, technical innovation, design revisions, economic considerations, and field support/maintenance [1].

**Learning Outcomes**

A key motivator for the program’s development was in 1996 when the Accreditation Board for Engineering and Technology (ABET) adopted the Engineering Criteria 2000 (EC2000) as the method for determining future engineering accreditation. The EC2000 shifted the focus away from the inputs (what material is taught) to the outputs (what students learned) [14]. The curriculum would require programs to assess and demonstrate their students’ achievement in 11 unique areas, ranging from technical knowledge, to communication skills, and the ability to work in a team.

**Women in Engineering**

Research on science education suggests that context is important to women students [15]. When working on EPICS projects, the students are provided with real-world problems and genuine context to design solutions around. Over twenty semesters, the average participation rates of women in EPICS were more than 70% higher than in their respective majors. In the past 20 years at Purdue University, the percent of women in Electrical Computer Engineering (ECE) and Mechanical Engineering (ME) ranged from 10% to 12%, while 20% of ECE and ME students in EPICS were women [16]. In another period of time, the enrolment rate in EPICS for women in Computer Science (CS) was nearly three times the enrolment rate of undergraduate women in CS [16]. Women have also taken on team leader roles at a considerably high rate. For a time period where women accounted for 20% of the students in EPICS, women represented 30% of the team leaders [16].

It is important to note that EPICS is an elective class that can be substituted for other types of technical electives in the students’ respective departments. This
means that women are choosing to enrol in the EPICS class since it is not required. Therefore, the higher rate of participation shows that they are drawn to the class [16].

The predominant reason most women choose to participate in EPICS was to obtain engineering experience. These women value the experience as a way to develop their own skill set and/or improve their resume for potential employers. Some female participants expressed strong interest in helping people as a reason for joining EPICS. One female in a study on EPICS noted the work as being in line with her desire to do not-for-profit work in the future [16].

After participating in EPICS, students cited two primary benefits: contextual learning and the team environment. Consistent with their desire to obtain engineering experience as the primary reason for enrolling in EPICS, a primary benefit from EPICS relates to context and learning. EPICS allows students to apply science and engineering concepts, principles, and equations to a real world problem. Not only are the EPICS problems themselves contextual, but participants find that the engineering experience is helpful in more ways than they originally anticipated because of the context it gives to their other classes [16].

Although not cited as a reason for choosing EPICS, the study participants were notably positive in commenting about the team experience and how it enhanced their learning. One student valued the different majors contributing to the team as a whole. Another student mentioned how working with more senior students helped her learn technical skills. The students also attribute the “project management” skills that they learn to the team structure of EPICS. They learn how to communicate and work with people from a variety of engineering disciplines and educational backgrounds [16].

**Student Retention**

Seven out of eight students in a study stated that EPICS increased or reinforced their commitment to engineering. One student talked about EPICS helping her stay in engineering by adding relevance to her early classes. Another commented on the value of seeing what it really means to work in an interdisciplinary team. It reinforced one student’s commitment to EPICS by helping her understand how her major and career interests fit together, as well as changing her views of the major itself [16].

In another study, Purdue EPICS found that the earlier one gets involved with EPICS, the higher one’s retention rate is. As you can see in Figure 5, joining EPICS in either the second semester of Freshman year (the earliest you can join at Purdue) or the first semester of Sophomore year, increases the Computer Science students’ chance at graduating by almost 20%. That percentage decreases as their initial involvement in EPICS is later in the students’ undergraduate careers [15].
Alumni Engagement

At Purdue University, there was a study done involving 551 EPICS alumni. 524 alumni completed a survey, and 27 were interviewed. As seen in Figure 6, it was found that over 75% of them attribute EPICS to improving their professional competencies to at least some extent. Just less than 75% of them attribute EPICS to improving their perspectives about engineering to at least some extent. Around 60% of them attribute EPICS to increasing their community engagement practice to at least some extent. It is important to note that just because students didn’t recognize EPICS’ benefit in certain areas, this does not mean that are unqualified or inexperienced in those areas. For example, they may already be very engaged in their local community, so EPICS would not necessarily impact that trait [15].

Other concrete examples of evidence that alumni highly value their experiences in EPICS surround efforts to support or expand EPICS after graduation. Many EPICS teams currently have corporate sponsorships that were initiated within those corporations by EPICS alumni. Creation of the first High School EPICS program came from EPICS alumni at the Naval Surface Warfare Centre and Visteon. There was a scholarship for Civil Engineering students involved in EPICS initiated and funded by EPICS alumni. Finally, an EPICS alumnus who won the ECE Alumni Design Award cited EPICS as the course having the most influence on his development as a design engineer [1].
Implementation

Staff
Implementing an EPICS-style program through iMMERSE will most likely require one staffed director to manage and facilitate the program. The director will be in charge of maintaining current project partner relationships, as well as finding new ones, and will also be in charge of assessing students in the program. If a new staff member cannot be hired, then it is recommended that the program be run with combined efforts between the Outreach & Community Engagement office and a Faculty champion.

Funding Options

The JW McConnell Family Foundation
The JW McConnell Family Foundation is a foundation dedicated to improving the quality of life in Canada by building communities, both locally and nationwide, that help people develop their potential and contribute to the common good. This is the best source of funding for a program like iMMERSE/EPICS due to its values, mission statement, and history of similar grant allocations [17].

From 2006-2009, the University of Sherbrooke received a $1,000,000 grant from the JW McConnell Family Foundation “to support the community service-learning project, which aims to transform its current community placements into more structured and sustained service learning” [18]. Soon after developing this
structure, they became a part of the EPICS University Consortium and implemented an EPICS program within their university.

From 2006-2010, the University of Ottawa received a $956,111 grant from the JW McConnell Family Foundation “to increase the breadth and depth of community service-learning (CSL) opportunities, by making CSL available in all 10 faculties by 2010. A total of 2,500 students, or 10% of the full-time student population, will be in CSL initiatives involving over 100 professors and 200 community organizations each year. This will provide community organizations with 75,000 hours of additional service per year. The expansion will be accompanied by significant new support, training and incentives for students, faculty and community groups” [19]. Making CSL available to all faculties through a multidisciplinary, vertically integrated approach is a key pillar of iMMERSE.

Other Options

A Faculty member recommended trying the Ontario Trillium Foundation for money, since they give out lots of money for specific, local projects. However, there may be restrictions for what organizations are allowed to receive funds, preventing McMaster from attaining any.

The program could be run via student money, either through course supplementary fees, or a student referendum, however the latter would require a campaign and would make it slightly more difficult to succeed. It is possible to also have the students fundraise their own budget. Instead of pre-allocating each team with a few hundred-dollar budget, force them to find sponsors and sell their product; this will teach them a whole new set of skills.

As seen at Princeton University, it is possible to combine a program like this with a research professor’s interests, without much cost to the Faculty. Essentially, the students would provide free assistance to further the professor’s research interests, assuming the students’ work is in line with EPICS core values. The program could also run through corporate partnerships, where students could work on problems for industry under corporate sponsorship.

Learning Portfolio

iMMERSE will require significant documentation to ensure students are learning and maintaining proper reports for transition purposes. The EPICS structure also requires a website to be maintained for dissemination of project information. iMMERSE will utilize the Learning Portfolio on Avenue 2 Learn for all of these purposes. Presentations will shared among team members and be used to display the team’s information, as well as the project’s progress and information. Personal Learning Portfolios can be used to imbed reflection pieces and engineering documentation into different project aspects that they have worked on, which then can be used for individual assessment and evaluation.
**Short Term**

While proper, complete implementation is under development, there are different aspects of iMMERSE that will begin taking place around the Faculty of Engineering. The vertical integration, and multiple year projects will begin through the Biomedical Design Project capstone course with Dr. DeBruin in ECE. He will be recruiting lower year students to join his Electrical and Biomedical capstone teams, which will also help transition purposes for his multiple year capstone projects. The network of contacts and projects is currently under development, and community-based projects can begin to be implemented into design project courses, such as capstones.

The Society for Engineering Application is a McMaster Students’ Union Club that gets engineering projects from industry for undergraduate students to take on. Their goals and values are very similar to iMMERSE, and they have become a partner for the 2013-2014 school year. They will use EPICS documentation to help structure their projects, which will be used as a pilot implementation of iMMERSE, although it will not have academic credit.

The program itself has received only positive feedback from Faculty and staff. It is still awaiting a Faculty champion in order to be implemented into the curriculum, although there are many interested potential candidates.

**Long Term**

It has been considered to be an excellent tool to demonstrate vision during the upcoming accreditation, and will ideally be completely implemented following the 2015 accreditation process. It is recommended that the program be rolled out in phases, with 3 or 4 departments starting a full implementation in September 2015, and the rest starting the following year. Ideally, it will eventually reach out to all Faculties on campus.

After iMMERSE is established as a separate course and projects are in place, the projects can also be integrated into current design courses, such as Engineer 1P03. The course currently uses a community-based project format, where all first year engineering students work with a single community partner to solve an engineering design problem. It is possible, with iMMERSE in place, to allow them to choose from and join one of the various project teams instead, so the project caters their interests, and so that there is the potential for them to continue working on the project after the single semester of 1P03. It also has the potential to replace the current course Engineer 4M06, the multidisciplinary capstone course. Students would be able to opt-out of the department-specific capstone to work, or continue working on, an iMMERSE project. Opting to use iMMERSE to fulfill an undergraduate’s capstone course requirement, will add additional expectations, which are available in the EPICS documentation.

iMMERSE is a unique experience that pushes students outside traditional educational boundaries, while simultaneously putting them at the centre of the
learning process. It hits strategic priorities both Faculty-wide and university-wide, and once in place, has the potential to push McMaster's student experience to the frontier of excellence.
Works Cited


