SHERIDAN JOURNEY: SHAPING IDEAL ENGINEERING PROGRAMS BASED ON CDIO APPROCH

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ABSTRACT

This paper presents the process of implementing the CDIO standards within Sheridan's Mechanical and Electrical Engineering Technology (MEET) School, housed within its Faculty of Applied Science and Technology. The School is in the process of establishing its first two engineering baccalaureate degrees in Mechanical and Electrical Engineering based on the CDIO approach. Eventually, all of the engineering programs across Sheridan College will be expected to adopt CDIO methodology. The effort aims to address a growing need for engineers who are not only technically competent but also maintain social skills essential to deal with current industrial challenges. Our expectation is to graduate "global engineers" with excellent technical knowledge; business competencies such as entrepreneurship and finance; and strong social competencies including teamwork and communication. To achieve this panoply of attributes, Sheridan adopted CDIO methodology as a guide to development of the curriculum for all of our newly proposed programs.

At the corporate level, the CDIO principles perfectly align with *Sheridan's Strategic Plan 2013-2020* which emphasizes creativity, innovative learning opportunities, and providing premier learning environments [1]. Mechanical and Electrical departments employed CDIO standards as a practical guide line to adopt these goals while maintaining an excellent undergraduate engineering program in Canada.

The proposed program focused on the design-implement approach, resulting in graduates who are "ready to work" engineers, capable of making immediate positive impacts on small and medium-sized enterprises looking for highly qualified technical personnel. Furthermore, this innovative approach supports Sheridan's strategic plan and expands collaboration with regional industries and educational institutions

KEYWORDS

Undergraduate engineering education, hands-on-experience, CDIO implementation, project based learning, CDIO standards: 3, 4, 5, 6, 7.

INTRODUCTION

For several years, Sheridan College's School of Mechanical and Electrical Engineering & Technology has been simultaneously partnering with small- and medium-sized enterprises on product and process innovation projects, while developing a Mechanical Engineering program based on project-based learning involving students, graduates and faculty mentors to address issues of product development/refinement, process automation, systems integration and manufacturing management. Over the past two years, this work has been bolstered by a range of successful, high profile, federally-funded projects with companies in Halton and Peel regions (Ontario, Canada).

The institution's commitment to expanding project-based learning and embedding it as a core teaching and learning activity is demonstrated by the work undertaken in the School of Mechanical and Electrical Engineering & Technology and the institution's Office of Undergraduate Research. The adoption of CDIO standards provided a unique, well-timed and powerful opportunity to not only support the project based learning environment, but also to initiate a fundamental reform in engineering education at Sheridan. The CDIO initiative restored the balance between teaching practice skills and the fundamentals of math and science, with effective hands-on engineering experience.

Adoption of CDIO was also supported by stakeholders in the regional engineering field, including industry, academia, and government, who recently expressed the necessity to reform engineering education to address the growing demand for specific engineering attributes. The proposed curriculum aims to graduate engineers who can address this demand with their technical expertise, system-level thinking, social awareness and capacity for innovation. This combination of skills and knowledge plays a crucial role in strengthening productivity and innovation within industrial sectors.

SHERIDAN STRATEGIC PLAN 2013-2020

In June 2011, Sheridan's Board of Governors endorsed a bold new vision for Sheridan, to establish Sheridan University, a unique undergraduate professional university founded on its reputation for creativity and innovation. This vision was subsequently reflected in the development of Sheridan's Academic Innovation Strategy, which outlines Sheridan's mission to "deliver a premier, purposeful educational experience in an environment renowned for creativity and innovation", rooted in key philosophies of creativity, innovation, design thinking and team-oriented, interdisciplinary curriculum. Sheridan's adoption of CDIO is timely in that there is strong alignment between the principles of CDIO and the characteristics of Sheridan's larger corporate strategic plan. Whereas in many contexts CDIO is advancing innovation at a curricular and program level, in the case of Sheridan, there are strong indicators of integration at the corporate strategic planning level as well. The following section presents the history and evolution of Sheridan to set the stage for a review of CDIO principles that are at work within the broader Sheridan strategic plan.

SHERIDAN HISTORY AND EVOLUTION

Sheridan began its life in 1967 as part of the newly established system of colleges of applied arts and technology that were created through legislation by the government of the province of Ontario in Canada. This addition to the tertiary education scene was viewed as critical by

the government of the day to keep pace with the skills requirements of the burgeoning and changing economy. It was evident to policy makers that a high school education alone was becoming inadequate to meet the requirements of the higher skilled jobs that were being created. As well, the university system was under-developed and was not preparing graduates for these skilled jobs; rather, their focus was on academic careers and the professions.

Over the close to 50 years since its establishment, Sheridan has grown from just a few hundred students to a comprehensive institution of practice-based learning with campuses in three of the fastest-growing Canadian communities in the Greater Toronto Area in southern Ontario. The full-time student population numbers close to 20,000 students from Canada and around the world, with international students comprising 17% of total enrolment. Sheridan offers more than 100 programs across a broad range of disciplines in Applied Arts, Engineering and Technology, Business and Social Sciences.

A key development over Sheridan's evolution has been the migration towards a broader range of credentials. When first established, Sheridan's focus was on shorter-term (1 and 2 year) certificate and diploma programs that were intended to prepare graduates for jobs. As well, these were intended to be terminal credentials that would provide the skills a graduate would need for a job for life. In today's environment with its rapid changes in advanced skills requirements and life-long learning expectations, Sheridan has evolved to increasingly offer Bachelor's degree programs with an applied focus, that continue to serve the needs of the economy, but also provide pathways to further graduate education. With the support of legislative amendments in 2002 that created the new legal entity of the Sheridan College Institute of Technology and Advanced Learning, Sheridan was empowered to offer a larger proportion of its programming at the Bachelor's degree level. Since that time the population of students in degree program has grown to approximately 20%, with considerable proportionate growth in this category still to come in the next five years.

With this history in place, in 2011 Sheridan embarked upon what has been called the Sheridan Journey with a new Board-approved vision to become Sheridan University. This multi-year effort will see Sheridan increase the enrollment of students in degree programming, develop and hire faculty with more advanced academic credentials, move towards a more bicameral form of governance with a stronger voice for faculty within decision making, enhance our library services, and incorporate new forms of applied research activity within and across the Sheridan curriculum. The above changes will provide the opportunity for Sheridan to obtain entry into the Association of Universities and Colleges of Canada. This is the organization that, in the absence of national institutional university accrediting bodies in Canada, is the proxy for national university recognition.

In travelling down the road to university recognition, Sheridan has engaged its academic community to describe the characteristics that best represent the Sheridan University of the future. It is through this process that the plan for the Creative Campus emerged. The following section reviews Sheridan's Creative Campus Strategy and draws parallels to the four high-level expectations in the CDIO syllabus.

CDIO PRINCIPLES IN A BROADER SHERIDAN "CREATIVE CAMPUS" STRATEGY

In the fall of 2013 Sheridan unveiled its new visual identity with a tag line that challenges people to "get creative." It's a bold and courageous statement that reflects Sheridan's belief that creativity is, among other things, an essential life skill. Our focus on creativity, which can

best be described as 'creativity with purpose' or 'practical creativity,' extends across all programs. It's about challenging students to re-imagine ideas, experiment, collaborate, take risks and build a resourceful, resilient and flexible mind. How realistic and authentic is this Creative Campus philosophy at Sheridan? How did this notion of creativity make its way into our mission, values and strategic goals?

Over the course of a number of months a representative body of Sheridan staff, administrators, faculty and students called Sheridan's Creative Campus Working Group collected feedback from the Sheridan community to better understand what creativity means to individuals across the college and how creativity plays a role within different areas of study at Sheridan. The group explored ways to describe how creativity and creative thinking are integrated into curriculum across the academic Faculties and identified some common domains of creativity at Sheridan. These include Creative Problem Solving, Reflective Thinking, Narrative Methodologies and Processes, and Community Engagement and Knowledge Mobilization. In addition to developing a degree level, cross-disciplinary elective that covers multiple approaches to creativity, the Creative Campus faculty group created a roster of online modules that may be used as needed to help professors embed creative activities into their lessons and enhance a range of courses across the college. A General Education elective entitled "Creative Thinking: Theory and Practice" is also offered to students in non-degree programs. Resonating in many of the themes of Sheridan's Creative Campus Strategy and the Sheridan Strategic Plan are the four expectations comprising the CDIO syllabus.

Disciplinary Knowledge and Reasoning

Sheridan prides itself on its history and legacy as an institution of applied learning that is strongly connected to the field of practice. This close connection to practice has ensured that our programs are constantly renewed and that our graduates are highly sought after by industry and ready to make a contribution in their employment setting immediately upon graduation. However, it is also important that our graduates are prepared to be critical thinkers and innovators within the field of practice. It is therefore important that Sheridan's programs walk the balance between applied technical knowledge and fundamental disciplinary knowledge. This balance is maintained through the interplay of Sheridan's Professional Advisory Councils and the expertise of our faculty as they engage together in the process of curriculum development and renewal. Professional Advisory Council members present information about the current state of practice and the competencies required by industry. Faculty members monitor the curriculum to ensure that it is broad enough to allow graduates to develop the critical thinking and creative problem solving skills they need to bring fresh perspectives to the field of practice and to enable them to build the resiliency that underpins successful and progressive careers.

Personal and Professional Skills and Attributes

Beyond the practical technical skills and the disciplinary knowledge that a Sheridan student obtains, there is another set of "Professional, non-technical" skills that are just as critical. Many leaders in industry are asking for graduates who can not only operate successfully within business and industry but who can help them design the workplace of tomorrow. This requires graduates who are able to exhibit creative problem solving competencies and who have strong ethics and personal resilience. As described above, the Sheridan Creative Campus initiative will ensure that all Sheridan students acquire these skills, both through elective courses that incorporate a methodology of creative problem solving, and also

through specially designed creative thinking modules that can be integrated into existing courses across all of Sheridan's programming areas. Sheridan has recognized that the economy and industry of the future will be increasingly fast-changing. Successful companies will be those that draw on the knowledge and wisdom that exists throughout an organization including that which can be found on the shop floor in order to innovate quickly. Sheridan is committed to ensuring that its graduates have the courage and the capability to contribute successfully to this evolving workplace.

Interpersonal Skills: Teamwork and Communication

The Sheridan Creative Campus model acknowledges that in today's world, activities are increasingly inter-related and global in scale. For this reason Sheridan is drawing strength from the diversity of programming that is found across the organization. Practically speaking, within the context of capstone student projects, students are being required to work in multi-disciplinary teams. Working collaboratively with industry partners, our creative campus model is bringing together such disparate programs as business, applied arts, early childhood education and engineering - just to name a few - to design and implement projects that solve real-world problems for business and industry. As these multi-disciplinary teams carry out their work, students are also honing their skills of communication and presentation as they interact with industry clients. As well, the rich diversity of cultural backgrounds and the engagement of international students are ensuring the teams are doing so in an environment rich with global experiences.

Conceiving, Designing, Implementing and Operating Systems in the Global Enterprise, Societal and Environmental Context.

The above-titled expectation of CDIO is particularly well embedded in Sheridan's creative campus model. There is a recognition that the increasingly inter-related aspect of today's industrial and economic systems require actors within those systems that "see the bigger picture." It is not sufficient for graduates of our systems of higher education to see themselves as simply a "cog in a wheel." Rather, they need to understand their roles as critical, integral and impacting upon the greater whole. For this reason, Sheridan is breaking down long-standing disciplinary barriers between different academic program areas. It is our view that no longer should any program be seen as an island because students will graduate into roles that will expect that they work in multi-disciplinary teams to solve the more complex inter-related problems of industry and society today. The deployment of the CDIO process at Sheridan in tandem with our own Creative Campus initiatives provides a unique opportunity to prepare more empowered graduates, who will drive innovation in business and industry and create more sustainable economic growth and development.

In order to implement the goals of Sheridan's Strategic Plan within the newly proposed Mechanical and Electrical Engineering degrees, the CDIO standards are employed as the skeleton of the program. The standards are designed to address the goals of initiatives [2,4] which are aligned with our institutional plan. The model was seen as a natural fit with Sheridan's vision, and can promote the program as a role model within Ontario's first undergraduate university dedicated to applied education and built in an environment renowned for creativity and innovation.

ADOPTION OF CDIO INITIATIVES IN THE SCHOOL OF MECHANICAL AND ELECTRICAL ENGINEERING (MEET)

MEET's new proposed engineering program is being developed based on key concepts of the CDIO methodology. This includes the precept that learning is best experienced in the context of experiential practice; and that faculty should include practitioners in the professional field, as opposed to pure academics and researchers. Meanwhile, the proposed program should provide learning opportunities for the students to develop personal and interpersonal skills such as teamwork, leadership, effective communication, project management, critical thinking, and creativity.

Our experience shows that one the most promising paths to achieving these attributes is to provide a collaborative environment for the students to engage in industrial projects through a gradual and structured approach. To this end, MEET has embraced project-based learning opportunities, and is actively seeking effective ways to integrate projects and problem-solving opportunities from industry partners into the learning experience. In the proposed mechanical engineering undergraduate program, this has been manifested in a variety of new delivery models for course material, which emphasize the development of personal skills including technical writing, communication and teamwork, integrated with learning in effective design and technical fundamentals.

In order to gradually develop capability in engaging with industrial projects, each student should progress through different levels of the competencies hierarchy:

- **Lower order competencies** reflect a student's ability to complete assignments such as labs and class assignments which are prescribed and have known solutions. The knowledge gained during these activities pertains to development of a structured approach to problem solving involving experimentation, observation, developing hypotheses, analyzing data and reporting. At this basic level, students need to learn and demonstrate knowledge of facts, concepts, principles, theories and definitions, and the skill of reporting that information accurately.

- **The middle order competencies** pertain to project work such as the standard "capstone" projects that most students complete in the final year of their programs. The proposed program will introduce these project courses earlier in the curriculum than traditional university programs, and emphasize the skills of independently defining a research problem, crafting a project scope, building and working in a team, managing project scope, budget, and timelines. In this level students are required to demonstrate the skills of comprehension and application of their newly gained knowledge to new, but still straightforward or routine, situations and contexts.

- **The higher order competencies** are associated with industry projects and applied research that are sponsored by industry. To complete this work, students must have mastered the lower level competencies of research management and will learn how to manage client expectations, negotiate scope and change orders, track budget, report research results, maintain effective communication with team and client, and deal with tighter timelines than most strictly academic projects require. The necessary skills therefore are those of analysis, synthesis, planning, designing and evaluation.

CURRICULUM STRUCTURE

The CDIO syllabus codifies what engineers should know and be able to do when they graduate. Major competencies include disciplinary knowledge and reasoning, personal and professional skills (like experimentation, prioritization, resourcefulness, self-awareness, ethics and integrity), teamwork and communications, and understanding the societal and enterprise context. The MEET development team believes that the new CDIO- based curriculum structure has a powerful impact on student learning. The proposed refined curricular model is intended to educate students in four major competencies: disciplinary knowledge and reasoning, personal and professional skills and attributes, interpersonal skills (teamwork and communication) and conceiving, designing, implementing and operating systems in the global enterprise, within a societal and environmental context. The curriculum is designed to embed the key CDIO standards and to ensure the framework achieves its objectives, among them: learning outcomes, integrated curriculum, and workspaces for social development. The following is a list of innovative features of the program:

Integrated Learning Blocks

A traditional curriculum is focused on a single aspect of a course title and is usually taught in a theoretical format without clear reference to engineering practice, training, and little if any connection to other courses. A traditional course is often stand-alone material arranged in prerequisite sequences. In contrast, the proposed curriculum, based on the CDIO Initiative, will be delivered in an integrated format. To provide more curricular flexibility and to incorporate new applications and emerging technologies, MEET will design and designate a set of classes as their mechanical engineering core, which all students would be required to complete. This core would consist of the first course in the fundamental mechanical and electrical engineering discipline areas. Once a student completes their core set of programs, they should be able to choose an option to continue their technical education. The proposed options, Mechatronics (within Mechanical) and Energy (within Electrical), fit the regional demand and align with faculty's industrial experience.

The proposed program includes several learning blocks. An example is the "Advanced Design" block which integrates Mechanical Design 2, Dynamics of Machines, and a Capstone Project which develops students' design capability in an integrated format, where students deploy their design and dynamics knowledge within their capstone project.

Implementation of CDIO-Bus Structure

The idea of CDIO-Bus structure is to allot time from two or more courses to be transferred to a connecting element that acts as a "bus" for the courses. In this approach, the bus is a multi-topic, open-ended project where the conventional courses are directly related to the bus. The advantage of this approach, which is suitable for fundamental courses, is that students who participate in the bus structure project address the outcome of different courses under the concept of a major project. This activity assembles the bus structure and develops multi-discipline projects for the fundamental courses offered in the first and second year across Mechanical, Electrical, and Computer engineering programs. "Magbot" project is a *bus* project designed for the junior level; the intention of this project is to engage students in design, development, and position control of a robotic arm with an electromagnetic gripper. The project includes design and fabrication of a wire truss as the arm of the robot, development of a position control strategy to pick and place a load, and competing for the

shortest time of travel among design groups. The Magbot is a perfect example of a bus project, including mechanical design of the truss, optimization, stability analysis, manufacturing concepts, system identification, control, system integration, mechatronics, and fundamentals of magnetism.

Introduction Engineering Course "Exploring Engineering"

The introductory course, usually one of the first required courses in a program, provides a framework for the practice of engineering. This framework is a broad outline of the tasks and responsibilities of an engineer, and the use of disciplinary knowledge in executing those tasks. Students engage in the practice of engineering through problem solving and simple design exercises, individually and in teams. The course also includes personal and interpersonal skills, knowledge, and attitudes that are essential at the beginning of a program to prepare students for more advanced product, process, and system building experiences. The course will be offered in the first year when students participate in small team exercises to prepare them for larger development teams.

CDIO-Engineering Workspaces: Building Spaces that Nurture Creativity

The physical environment for the program includes learning spaces such as flexible classrooms and seminar rooms. In addition, MEET remodeled and renovated engineering workspaces and laboratories that provide the physical environment to support and encourage hands-on learning of product, process, system and social building skills concurrently with learning disciplinary knowledge.

These workspaces, which are different from traditional classrooms, provide the opportunity for social learning; that is, settings where students can learn from each other and interact with several groups. Such competencies are best developed in workspaces that are student-centered, user-friendly, accessible and interactive. CDIO engineering workspaces provide for conceptual development and reflection, digitally-supported design, and systems integration as well as testing and operation.

CONCLUSION

The purpose of engineering education is to provide the learning required by students to become successful engineers – technical expertise, social awareness and a bias toward innovation. This combined set of knowledge, skills, and attitude is essential to create abilities that strengthen productivity, entrepreneurship, and excellence in an environment that is increasingly based on technologically complex and sustainable products, processes and systems. It is imperative that the quality and nature of undergraduate engineering education are continuously transformed to lead the way. Being cognizant of these multifaceted perspectives, the School of Mechanical and Electrical Engineering and Technology, within the Faculty of Science and Technology at Sheridan College, has begun the process of creating baccalaureate level degree programs in Mechanical and Electrical Engineering while shaping an ideal engineering school based on the CDIO approach. Sheridan has been pleased to become a member of CDIO and is moving forward with its integration into all of our Engineering programs. What has subsequently been recognized is the relevance that the CDIO process has for disciplines beyond engineering and, indeed, its strong potential to advance the Sheridan strategic plan. The next steps will be to explore the further integration of the progressive themes of CDIO into other areas of institutional practice.

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BIOGRAPHICAL INFORMATION

Jeff Zabudsky, Ph. D. is President and CEO of Sheridan College in Ontario, Canada. He was appointed President in 2010 . He was previously President of Red River College in Manitoba, Canada and has worked across Canada in post-secondary education and educational broadcasting for close to 30 years. Dr. Zabudsky holds a PhD from the University of Alberta, Masters degree from Athabasca University and an undergraduate degree from Ryerson University.

Farzad Rayegani, Ph.D., P.Eng., FEC is a Professor in Mechanical Engineering and Associate Dean of the School of Mechanical and Electrical Engineering & Technology at Sheridan College, Brampton, Canada. As a CDIO collaborator, he is seeking to develop new curriculum structures based on a new philosophy for engineering education. The framework educates students to Conceive, Design, Implement and Operate complex, value-added engineering products, processes and systems in a modern, team-based, global environment.

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