The Power of Creative Space in Engineering Education

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ABSTRACT

In order to graduate globally capable engineers who are not only technically savvy, but socially competent and business smart, Sheridan's School of Engineering has found both a process and a 'place' to meet these goals and align with their vision to create curricula that inspire innovation and creativity. The process: the CDIO methodology that helps graduate "ready to work" engineers. The place: Sheridan's Centre for Advanced Manufacturing and Design Technologies (CAMDT).

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?

For the CDIO methodology to translate into outcomes, students need the creative space to get the real world practice that makes CDIO such a powerful learning strategy. Operating like a research and development arm for small and medium sized enterprises, CAMDT unites engineering students, faculty and community partners to solve real world challenges and produce solutions that benefit the local economy. At Sheridan, CAMDT is not just a physical space, it's a creative space where the collaboration between engineering students, educators, industry and community partners not only benefits enterprise partners, but helps Sheridan shape engineering education.

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 paper reviews Sheridan's Creative Campus Strategy and draws parallels to the four high-level expectations in the CDIO syllabus.

KEYWORDS

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

THE CREATIVE CAMPUS: CREATIVITY AT SHERIDAN

Introduction to the Creative Campus

In the fall of 2013, Sheridan unveiled its new visual identity with a tag line that challenges people to "get creative." It is a bold and courageous statement that reflects Sheridan's belief that creativity is, among other things, both a mindset and 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 is about challenging students to re-imagine ideas, experiment, collaborate, take risks and build a resourceful, resilient and flexible mind. As a broader strategic mandate, we have embraced a Creative Campus philosophy that is based on the premise that creativity resides in people, programs, place and space, and in everyday institutional processes. The concept of the Creative Campus is grounded in our continued desire to weave creativity into all that is Sheridan, so that teaching, learning and doing at Sheridan reflect a "commitment to the advancement of creative capacity, creative engagement, collective wisdom, and people success."

Creativity in Programs and Curriculum

Creative and critical thinking competencies, alongside creative problem solving skills, are increasingly celebrated as top-ranked, essential proficiencies in the highly competitive workforce of the 21st century. It is no surprise that the New York Times has recently published an article about the proliferation of post-secondary programs that formally recognize creative thinking as an essential academic disciplinary area. To that end, Sheridan has developed a brand new credential in Creativity Studies. As of January 2015, students enrolled in degree programs at Sheridan have the opportunity to pursue a Board Undergraduate Certificate in Creativity and Creative Problem Solving while fulfilling their liberal arts and science breadth requirements. The new credential reflects Sheridan's adoption of creativity as a cornerstone of its institutional identity and pedagogical approach, based on an understanding that creativity and creative problem solving are essential skills for the 21st century across all disciplines and fields of study.

According to an IBM Global CEO Study undertaken in 2010 which surveyed 1,500 CEOs worldwide, creativity is the most crucial factor for future success in an increasingly complex world. Further, in "Innovation Skills Profile 2.0," published by the Conference Board of Canada's Centre for Business Innovation, "Creativity, Problem Solving and Continuous Improvement Skills" comprise the top category of skills required to contribute to an organization's innovation performance and thereby "produce new and improved strategies, capabilities, products, process, and services." In response to these findings, Sheridan now provides students with an opportunity for outstanding training in a cross-disciplinary, structured and highly rigorous creative problem solving environment, so that students may acquire the skills and develop the mindset to meet a growing market demand for creativity and enhance Canada's innovative capacity. Over the four years of their degree program, students may take six courses that span a range of disciplines and subject areas in the fields of global culture, humanities, and social sciences. The curriculum has been endorsed by the International Center for Studies in Creativity (ICSC) at Buffalo State, SUNY. Through a Memorandum of Understanding, students who have completed Sheridan's Board Undergraduate Certificate and meet admission requirements will be eligible for graduate and post-graduate studies at the ICSC, Buffalo State.

Importantly, the new credential and associated pathways serve to reinforce and supplement the innovative approaches to learning that already exist in the context of each degree program, and to realize Sheridan's commitment to a vision of becoming "a university that is celebrated as a global leader in undergraduate professional education" with a mission "to deliver a premier, purposeful experience in an environment renowned for creativity and innovation."

Creativity in Space and Place

As an essential step in the Creative Campus journey, Sheridan has committed to an exploration of creative learning environments and, more specifically, creative approaches to space and place. How might we create physical and virtual learning spaces that encourage collaboration, inspire cross-disciplinary exchange and exude energy, authenticity and an unquestionable commitment to creative engagement? In an effort to recognize the relationship between space, place and engagement in the context of educational settings, Sheridan has struck a Creative Campus Advisory Council that consists of members from a range of domains at Sheridan who have come together to envision an engagement framework for public, creative and scholarly activities. The aim is to imagine an institutional cross-Faculty unit, a dedicated Institute for Creativity, which serves to embody Sheridan's commitment to purposeful creativity and act as an established hallmark of Sheridan's Creative Campus, while occupying physical and virtual space. The Council brings together disciplines, departments and people in order to catalyze and support advanced interdisciplinary exchange in the form of scholarship, research, conversation and a spectrum of creative initiatives; at the heart of its vision is an emphasis on collaborations and inspired connections which serve to open and expand the relationship between Sheridan and the wider community.

While our commitment to creative space spans across all four campuses, we are particularly deliberate about leveraging opportunities to integrate the creative campus vision into the architecture of new spaces. For example, we are in the process of expanding our Hazel McCallion Campus in Mississauga with a second building that is due to open in September, 2016. As a 220,000 square foot facility, the building will be home to programs that have been grouped into clusters to encourage collaboration – these include: the Sustainable Built Environment (including Architecture, Interior Design, Interior Decorating), Creativity and Communications, as well as Business, Advertising, and Visual Merchandising. More specifically, the new building will include new studios, labs and production spaces, new classrooms, as well as a unique Creative Campus Complex comprising a series of interconnected elements such as a Creativity Commons, a creative gallery, a specialized flexible creativity classroom, and dispersed pockets of collaborative space that are conducive to serendipitous interaction, experiential learning and informal chance encounters. When all is said and done, our Mississauga campus will be home to 5,600 students who will have an opportunity to engage in new ways with their learning space. Appropriately, the new building will also help Sheridan set a new standard for sustainability when it comes to construction and energy efficiency, affirming our commitment to a creative campus that is reflected inside the structure of our buildings and extends to the way we *conceive*, *design*, *implement* and *operate* our space.

As we look toward the realization of newly built structures, we continue to develop the creative capacity of our current landscape in an effort to promote internal and external engagement, experiential collaboration and undergraduate research, and cross-disciplinary activity. For example, as part of our Creative Campus agenda, the Faculty of Animation, Art

and Design has embarked upon the enhancement of our campuses through Public Art installations, while the Faculty of Applied Health and Community Studies has created a Community Builder Series; the Faculty of Humanities and Social Sciences has initiated a Sheridan Reads project for the internal community and wider public, and the Faculty of Applied Science and Technology has created Sheridan's Makerspace Creative Hub, a signature space that is marked by its commitment to the *CDIO* approach. The intent is to mobilize the kind of learning that extends beyond curricular boundaries and offers the type of continuous engagement that transcends academic borders and transforms academic space.

CDIO CURRICULUM STRUCTURE AT SCHOOL OF ENGINERING

At Sheridan, We fully understand that today's knowledge economy requires engineers who are creative problem solvers and whose ideas and innovations help shape the future. We further understand that what truly sparks innovation and excitement in students is the practical application of fundamental principles in the form of experimentation and hands-on experiences. We have tackled these concepts with the creation of new curriculum at Sheridan based on CDIO framework (Crawley, E., et al., 2007). Throughout the development process, the CDIO (Conceive–Design–Implement–Operate) approach has been the guiding principle in creating the graduate attributes and program design.

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 projects through a gradual and structured approach. To this end, school of engineering 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.

The associated CDIO™ syllabus and standards (Cloutier, G., et al., 2010) have been followed in developing the program, and subsequently, in developing the contents, evaluation methods, and teaching methodology in consonance with CDIO™ goals. The graduate attributes of the proposed program are comprehensive in nature. The CDIO™ approach aims to address a growing need for engineers who are not only technically proficient but also maintain social and practical skills essential to deal with global challenges. These skills include, but are not limited to, business knowledge, systematic thinking, creativity, entrepreneurship, leadership, and problem solving. The proposed program curriculum is designed to provide students with opportunities to effectively develop students' technical and functional expertise. The mechanical engineering curriculum focuses on innovation, design, hands-on-experience, multi-disciplinary communication, teamwork and problem solving.

Integrated learning is a key feature of the Sheridan's CDIO™ program where students learn personal, interpersonal and system building skills together with disciplinary knowledge in the context of professional engineering practice. The proposed methodology of the mechanical engineering program is based on the integration of project-based learning throughout the entire engineering program. This instructional method encourages students to develop their problem solving and critical thinking skills through their involvement in real-life industrial projects. In this approach there is less emphasis on passive transmission of information and more emphasis on engaging students in manipulating, applying, analyzing, and evaluating ideas.

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

Sheridan's engineering programs are 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.

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Creativity in Engineering Programs and Curriculum

According to the National Academy of Engineering (NAE), the Engineer of 2020 should display the following qualities (National Academy of Engineering, 2004):

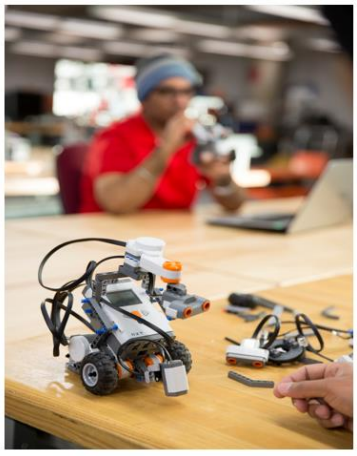
- Strong analytical skills
- Practical ingenuity
- Creativity
- Communication
- Business and management knowledge
- Leadership
- High ethical standards and professionalism
- Dynamism, agility, resilience, and flexibility
- The habit of lifelong learning

The diversity of this list highlights the notion that undergraduate engineering programs should help students acquire a broad range of skills beyond theoretical knowledge in order to compete in an increasingly competitive global environment. Engineers need a creative mind to meet the advancing goal of the engineering profession to Conceive, Design, Implement and Operate complex, value-added engineering products, processes and systems in a modern, team-based, global environment (Crawley, E., et al., 2007). In order to gradually develop such a capability and skill sets, each student should progress through different levels of the competencies hierarchy.

According to Taylor (I. A. Taylor, and J. W. Getzels, 1975), creativity is perceived as a hierarchy from a low to a progressively higher level. The first level includes expressive creativity which reflects a student's ability to develop a unique idea with no concern about its quality (Zhiqiang Liu et al., 2004), by completing assignments such as labs and class assignments which are prescribed and have known solutions. The knowledge gained during these creative 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 (Figure 1.).

EXPRESSIVE CREATIVITY	
Principles of Engineering & Design	
Activity	Implement - Operate
Structure	Structured
Solution	Known
Team	Individual / small team
Duration	Days

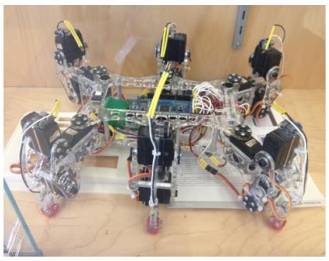


Courtesy of Sheridan College / CAMDT- MEET

Figure 1: Ex.: Building a model airplane / Robot from a kit

The second level is defined as technical creativity, the proficiency to create products with consummate skills, but with little expressive spontaneity (Figure 2.). Technical creativity pertains to project work such as the standard "Design" projects that most students complete in the 2nd or 3rd year of their programs. It emphasizes the skills of independently defining a design 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.

TECHNICAL CREATIVITY	
ENGINEERING BY DESIGN	
Activity	(Design), Implement and Operate
Structure	Structured
Solution	Known
Team	small team
Duration	Days



Courtesy of Sheridan College / CAMDT- MEET

Figure 2: Ex.: Design and fabricate robot arm

The third level includes inventive creativity, the ability to re-engineer parts or develop, design new product (Figure 3.). At this level, they must learn how to link science and engineering to the needs of society, and able to communicate that to the public. Here the engineering

student creates a prototype, the first of its kind based on the process of combining older ideas and synthesizing them into a new product.

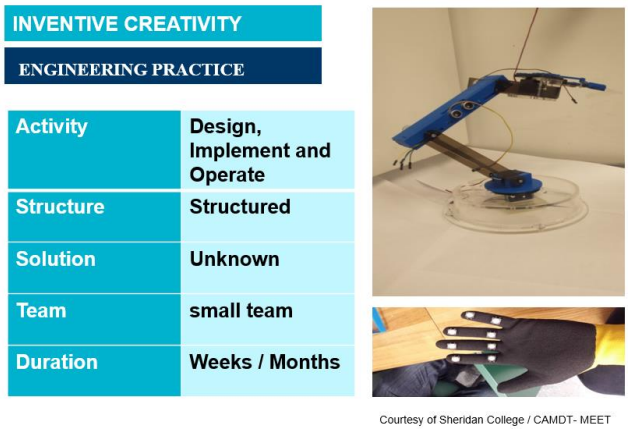


Figure 3: Ex.: Design and fabricate remote controlled 5 axis robot arm manipulator

The fourth level, innovative creativity, is the ability to penetrate foundational principles or establish a school of thought, and formulate innovative departures. The engineering student is able to `think outside the box', to move beyond the current thinking of engineering and develop a new way of creating and designing (Figure 4.). To complete this work, students must have mastered the lower level competencies of “design, Implement and Operate “ and 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.

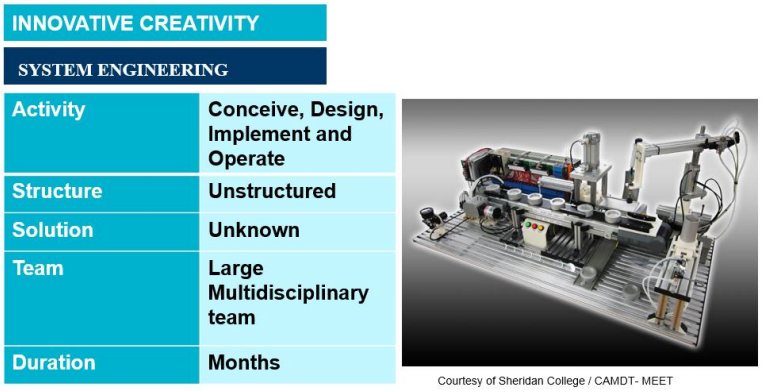


Figure 4: Ex.: Building a Flexible Manufacturing Cell / System

The fifth and highest level is emergent creativity, the ability to incorporate the most abstract ideational principles or assumptions underlying a body of knowledge, as in the example of Einstein's work on general relativity (Zhiqiang Liu et al., 2004). For undergraduate engineering programs, setting the highest goal at a level of `innovative creativity' may be more realistic and achievable, considering the facts that engineering is a profession where

scientific principles or findings are applied to produce useful products and services (M. C. Shaw, 2001).

CDIO-Engineering Workspaces: Building Spaces that Nurture Creativity

The physical environment for the engineering program includes learning spaces such as flexible classrooms and seminar rooms. In addition, engineering school 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.

Creative Space and CDIO: Sheridan's MakerSpace Creative Hub

Sheridan's Centre for Advanced Manufacturing and Design Technologies along with Brampton Library and the City of Brampton Economic Development office have established a creative workspace in downtown Brampton where residents, students, entrepreneurs and visitors can collaborate while sharing tools, resources and knowledge.

Using a makerspace model, the MakerSpace Creative Hub combines state of art technology with community and education to help users *Conceive, Design, Implement and Operate* manufactured works that would not be possible to create with the resources available to individuals working alone. It is also a great place to learn how to use cutting edge tools, and to develop 21st century job skills.

MakerSpace Creative Hub missions:

- Support the creative economy by engaging community groups, attracting entrepreneurship and introducing technology resources to a wider audience, thereby helping to foster the development of 21st century job skills.
- Create opportunities for collaboration, learning, mentoring, and innovation.
- Provide residents and community groups with free access to tools and resources to solve household or commercial design challenges, or simply create and play.
- Empower community residents to learn new skills, develop products and create art.
- Provide shared workshops, tools, services, and training for artists, designers, inventors, engineers, architects, makers, hobbyists, and other creative people.
- Enhance the reputation of the region as a creative hub; and contribute to the quality of life and economic development.

CONCLUSION

Engineering educations are increasingly expected to provide more opportunities that foster and nurture creativity in engineering students. More importantly, they should demonstrate original and critical thinking, and creativeness and innovativeness in their methodologies. Since creativity emanates from problems, it seems more natural for engineering students to gain creativity through practice of problem solving, as they are inevitably expected to be effective and creative problem-solvers. Methodology of the engineering programs at Sheridan College is based on the integration of project-based learning throughout the entire engineering program. This instructional method encourages students to develop their problem solving and critical thinking skills through their involvement in real-life industrial projects. In this approach there is less emphasis on passive transmission of information and more emphasis on engaging students in manipulating, applying, analyzing, and evaluating ideas. Creative space is critical pillar of this approach.

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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.

Yael Katz, Ph.D. currently serves as Special Advisor, Creative Campus, in the Office of the Provost and Vice-President, Academic, at Sheridan College. She is also Associate Dean in the Faculty of Humanities and Social Sciences, where she provides leadership in the areas of Humanities and Creativity. Dr. Katz completed her Ph.D. in English at the University of British Columbia, where she was a member of Green College, an interdisciplinary graduate college committed to open and creative interdisciplinary exchange. As part of her doctoral studies, she attended the School of Criticism and Theory at Cornell University. She holds a Master of Arts and an undergraduate degree in English from the University of Western Ontario. As an advocate of Sheridan's commitment to creativity and the Creative Campus, she has led curriculum development and engagement initiatives in the areas of creative thinking and creative problem solving, and is interested in cross-disciplinary approaches to creativity as a concept, mode of practice and emerging area of study, research and thought.

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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