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Landscape Review of Entrepreneurship Education in Canada and the Presence of Systems Thinking

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Abstract

Entrepreneurial activities have been driving forces of economies worldwide, bringing innovation and change to societies and pulling countries out of recessions. Increasingly, technology-driven innovation and entrepreneurship have become the key competitive advantages for a region or nation. There has been a push for universities to produce more entrepreneurs that can handle the challenges of today's world, and many engineering programs have begun to incorporate entrepreneurial education. Additionally, there has been an increased emphasis on systems thinking as an important capability for engineers as they seek to address complex challenges. This paper describes a scan of program offerings at Canadian post-secondary schools that address the topics of Entrepreneurship and Innovation and looks for evidence of Systems Thinking Teaching within the courses and curriculum.

Keywords

Systems thinking, Engineering Education, Canadian Education, Landscape Review, Entrepreneurship, Entrepreneurship Education.

Background

There is little doubt on the benefits of entrepreneurship in an economy's development. Entrepreneurial activities leading to small and medium-sized enterprises (SMEs) have been consistently shown to create more jobs, wealth, and innovation in a region. In developed economies, SMEs make up a large portion of the businesses, responsible for 60-70% of employment and up to 50% of gross domestic product (GDP) [1], illustrating the value of entrepreneurship in job creation. The government of Canada recognizes the importance of entrepreneurship in the development of its economy, with small and medium-sized enterprises (SMEs) accounting for 98% of businesses and employing 8 out of 10 private-sector workers [2].

New products are often first brought out by entrepreneurs. These products could also include various services, technologies and specific advancements in a sector or industry [3]. Research has shown a positive association between entrepreneurial activities and levels of innovation [4]. A challenge is finding methods that could lead to fostering fast and scalable entrepreneurship and foster the culture of risk taking, experimentation and competitiveness amongst businesses.

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Governments around the world increasingly invest in entrepreneurship as they have realized its importance for economic growth, job creation and competitiveness [1]. Countries that actively promote entrepreneurship have higher rates of business creation and innovation [5]. Government mechanisms to support entrepreneurship take shape in the form of policies, access to funding, tax incentives, regulatory initiatives and education programs. The emphasis on education has been increasingly apparent for entrepreneurship and various tools and techniques are being used to promote entrepreneurship and complex problem solving in education [6]. Canada is investing heavily in entrepreneurship and is looking for tools to increase the entrepreneurial outcomes of educational institutions [7]. The Canadian government has invested $14 million in funding to support the creation of jobs and growing of the economy in Greater Toronto Area (GTA) alone. This includes funding programs distributed to existing corporations and programs that support recent graduates in their entrepreneurship journey.

Systems Thinking (ST) could be a beneficial tool for helping scale entrepreneurship, specifically in the engineering context. ST has been demonstrated to enhance innovation, while design processes have been used to inspire ST in engineering curricula [8]. ST has been also used by small and medium business managers to help navigate the complexities of the business environment which is not only due to multi-stakeholder involvement but also caused by the challenges from accelerating economic, technological, social, and environmental change [35].

To elucidate the connection of ST, entrepreneurship and engineering education, we explore the Systems Thinking and Entrepreneurship literature, and highlight the potential crossovers of these fields. We also review the ways in which Systems Thinking is being delivered in Canadian post-secondary education system, within and beyond engineering.

Canadian Education

The Canadian post-secondary education system is one of the most advanced education systems amongst modern countries. Canada has 26 universities in the top 800, with five in the top 100, according to the 2021 QS World University Rankings [9]. This is a testament to the country's commitment to providing a world-class education to its students.

Diversity is one of the Canadian education systems' most prominent factors. The country is home to a wide range of universities, including large research-intensive institutions, small liberal arts colleges, and specialized schools. This diversity allows students to choose the type of institution that best suits their needs and interests. Additionally, Canada's post-secondary system is known for its focus on hands-on learning and real-world experience. Many institutions offer co-op programs and internships, which give students an opportunity to gain practical skills and experience while still in school [10]. There are also around 150 university accelerator and incubators in Canada that support entrepreneurship in various fields of work and levels education, illustrating the diversity at all levels of education and practice [11]. University-based accelerators are university-based hubs where future startups can train for their future success and challenges, get funding and mentorship support [17].

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Canadian education is increasingly committed to an interdisciplinary and collaborative approach in learning, to prepare students for the tackling real-world problems. This effort is more prominent in some fields such as health than others [12]. Many institutions are offering programs that bridge different disciplines, such as business and engineering or science and policy, to equip students with the skills and knowledge they need to tackle complex and multifaceted problems. Additionally, Canada has launched many initiatives to better prepare students for the latest advances in their fields and future careers by focusing on research and innovation.

Systems Thinking

Systems Thinking was developed from the General Systems Theory of Bertalanffy and has been applied to a wide range of fields and disciplines including health care, management and business, plant manufacturing and sustainability [13]. Systems Thinking is utilized for its ability to address complex problems, explore non-linear relationships, and tackle socio-technical and economic challenges [14]. It has a range of applications and is not limited to a specific discipline.

As summarized by Monat and Gannon, "Systems Thinking is a perspective, a language, and a set of tools" [15]. Systems Thinking (ST) incorporates a holistic view of a problem and focuses on the relationships between components of a problem, helping recognize repeated events or patterns, behaviors, and mental models [15]. ST emphasizes the interconnectedness of different elements within a system, and how changes in one part of the system can affect the entire system.

ST has been used in education through its application to various fields such as science, mathematics, social studies, and even language arts. An example of the application of ST in environmental sciences is helping learners understand the feedback loops of carbon emissions and their effects on the entire environmental ecosystem [16].

ST methodologies can help learners understand the complexity of some of the real-world problems they interact with and look beyond the linear approaches in solving them. It also helps learners through development of the skills and knowledge required to tackle wicked problems, pushing learners towards critical thinking, problem-solving, and decision-making skills, which are important for success in any field [15].

Some of the Systems Thinking tools include actor maps, systemigrams, system archetypes, main chain infrastructures, causal loops with feedback and delays; stock and flow diagrams; behavior-over-time graphs, computer modeling of system dynamics, Interpretive Structural Modeling (ISM), and systemic root cause analysis [15].

Entrepreneurship and Systems Thinking

Entrepreneurship is the process of building a business to fill in a gap in the market [18]. Entrepreneurship in the context of Systems Thinking refers to the process of creating and

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managing a new venture while considering the interconnectedness of different elements within the system, and how changes in one part of the system can affect the entire system. ST also looks at a business as a complex and dynamic system which is affected by number of factors including internal operations and external environments [19].

Researchers argue the benefits of ST in Entrepreneurship using different lenses. First, using ST, entrepreneurs can identify and understand the complex challenges and opportunities that come with starting a new venture and develop more innovative and resilient business models. By examining the various components of a business system, including its environment, inputs, processes, and outputs, entrepreneurs can gain a better understanding of how each component impacts the overall performance of their venture [20]. This can lead to more effective problem identification and resolution. For example, Systems Thinking can be used to identify the root cause of a problem rather than just addressing the symptoms, leading to more sustainable solutions [19].

The application of Systems Thinking and Business Model Innovation (BMI) has been studied by researchers such as Halecker in the field of Management and Entrepreneurship and has been shown to be promising [21]. ST can help entrepreneurs to anticipate and adapt to changes in the market and external environment, which is especially important in today's rapidly changing world. ST can be used in areas such as developing and updating new business models through revealing previously uncovered connections and avoiding isolated analysis [21]. Moreover, Systems Thinking encourages entrepreneurs to take a holistic approach to business creation, by considering not just the product or service they are offering, but also the broader context in which their business operates. This includes understanding the relationships between different stakeholders, such as customers, suppliers, competitors, and regulators, and how these relationships can impact the success of the business [22]. Through the ST approach, entrepreneurs could analyze the business as a whole and identify and manage potential areas of risk, improve efficiency, and develop innovative strategies to drive growth [20]. ST also helps entrepreneurs to identify the underlying factors that drive business performance, such as the impact of external environmental factors and the interrelationships between various components of the business [19].

Entrepreneurs who adopt a ST approach are also more likely to consider the long-term sustainability of their business, rather than just focusing on short-term gains. This may include considering the environmental and social impact of their business, and how it can contribute to the greater good [23] or ways in which the business can reduce the environmental impact of their operations [24]. Knowledge of ST can also set entrepreneurs a step ahead of others in anticipating and responding to changing conditions such as market disruptions or shifts in the regulatory requirements, in a more strategic manner [20].

In their study of entrepreneurship and strategic thinking, Pisapia and Jelenc found that ST has been demonstrated to be a significant predictor of all three elements of individual entrepreneurial behavior which include risk-taking, innovativeness, and proactiveness [25]. ST contributes to “innovativeness by providing rational sources of patterns and interrelationships that already exist and, at the same time, lack on the market”.

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Methodology

An analysis was conducted of the websites of Canadian post-secondary Institutes to look for educational programs offered by any department at any level of study that claimed to teach Systems Thinking. This was done by searching for the school's name, followed by the term "Systems Thinking" as a Google search. All the webpages identified for a given institution were later evaluated and the contexts from the page were looked at with the intentions of finding details on the courses, minors, certificates, degree, or competitions with the main idea of "Systems Thinking" or "System Mapping". Once the webpages were proven to be an appropriate source of information, a web scraping tool was used to record the relevant context of the page and monitor with the appropriate tags.

Tagging was done to further analyze the data once the web scraping was completed. The purpose of the tagging was to categorize the data into separate contexts such as the "Type" of the learning material, the relevant "Education Institute", the "Level", and the "Subject" of the learning material.

The "Type" of the ST offering highlighted the difference between the learning offerings. The items in this category include, "Course", "Degree", "Minor" and "Certificate". Certificate refers to a cluster of courses from an institution to indicate that learners have taken the appropriate material related to a specific field of knowledge. Minor indicates a more significant degree of specialization.

Programs were more specifically branched into "Levels", namely "Ph.D.", "Masters", and "Bachelors". This was done since some of the courses offered were tailored towards a certain category of students from a specific department. The "Education Institute" is relatively clear to understand. Each data point was retrieved from a specific post-secondary institution in Canada and therefore, the information gathered from the websites needed to be additionally clarified and associated with one of these post-secondary institutions.

The "Subject" category is the subject of the course that is using Systems Thinking tools and techniques. There was a range of courses using Systems Thinking principles to tackle a wide range of problems across different fields of study, from engineering to business to healthcare. The home department teaching these courses along with an analysis of the case studies in the course determined this analysis.

Results

Distribution of the "Education Institutes"

A total of 24 ST offering types were identified instruction across 18 Canadian post-secondary institutes. 12 out of the 18 post-secondary institutions offering Systems Thinking were among the top 20 Canadian Universities according to the QES [26]. Out

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of the 18 institutions that teach Systems Thinking content, 14 delivered through courses, 3 through certificates, 5 as degree programs. One program offered an ST minor.

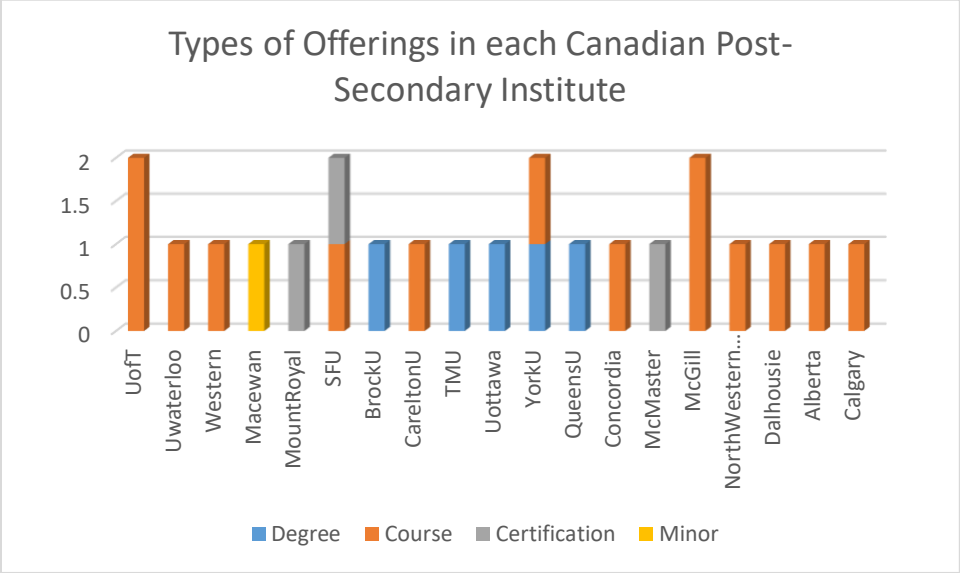

Figure 1. Different types of programs offered in Canadian Post-Secondary Institutes

Figure 1 demonstrates the various types of offerings in Canadian post-secondary institutes. Figure 2 displays the distribution of types of ST offerings provided across various post-secondary institutions in Canada.

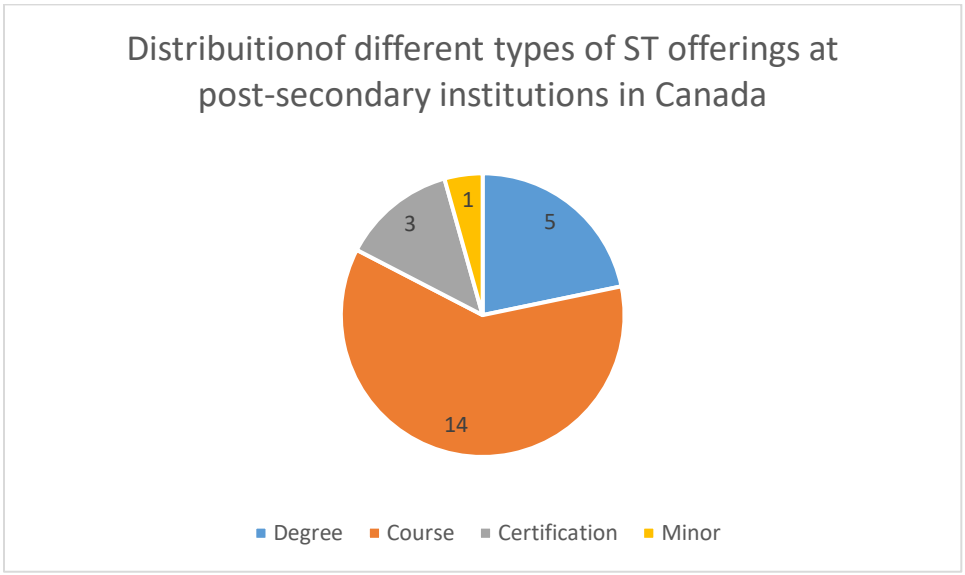

Figure 2. The different Systems Thinking programs offered by post-secondary institutes in Canada.

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Distribution of the "Subject" of courses

Systems Thinking content was offered across a wide range of subject areas. Healthcare and Sustainability were the most frequent subjects, while Business, Engineering, and Continuing Education programs also offered system thinking subjects. The other category includes subjects such as policy [27], communications [28], social innovation [29] and other research initiatives [30]. Figure 3 demonstrates a breakdown of these categories.

Business programs had the majority of the share of Systems Thinking related offerings, with a distribution of courses [2/5], minors [1/5], certificates [1/5] and degrees [1/5]. Almost all [4/5] of the programs were targeted to graduate students. Out of the 5 Health Sciences related programs, [2/5] were targeted to bachelor students and 3 were focused on graduate students, with a majority [4/5] being offered as courses and only [1/5] offered as a certificate. Of the total of 4 Sustainability-related Systems Thinking programs, [¾] were offered as courses, with an even split between bachelor's and graduate program offerings. There was a total of 4 Continuing Education programs that were solely focused on graduate students and were only offered as courses.

There were of 2 Engineering programs offering Systems Thinking instruction; both were targeted to bachelor level students, with one being a course and the other being an undergraduate engineering program, aimed to familiarize students with Systems Thinking concepts in Engineering [31,32].

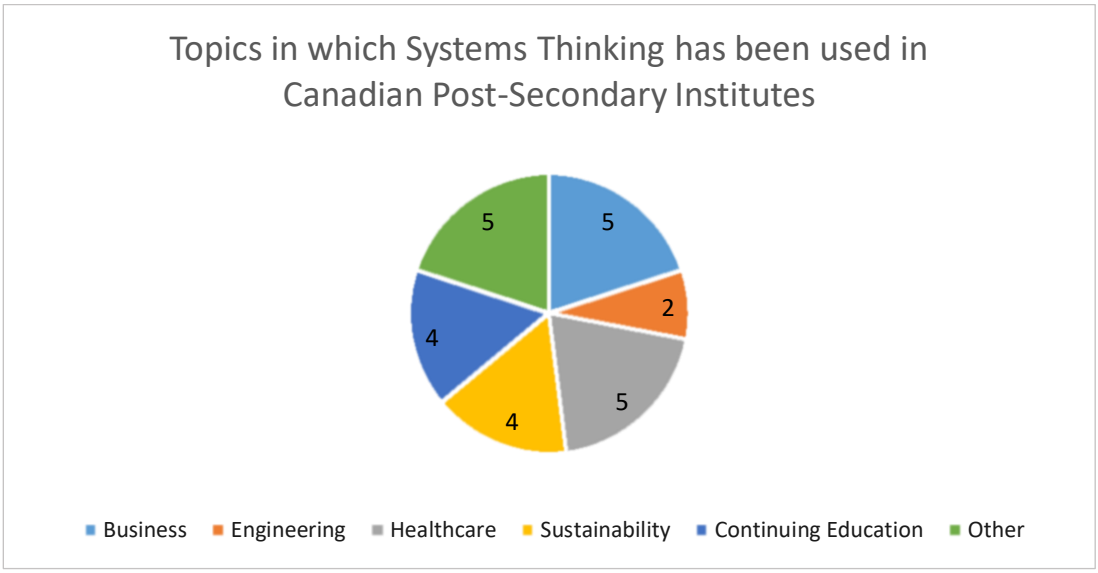

Figure 3. The distribution of Systems Thinking topics used in Canadian Post-Secondary Institutes

ST in Business was used as a strategic lens for complex problem solving inside and outside of organizations. Some of the problems addressed include supply chain management, procurement, logistics, business intelligence and transportation [33] with the main claim that ST could be used as a "method and tool for working with change,

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solving complex problems, and creating individual and team learning" [34]. This suggests that most Business related ST strategies are thought as a method for problem solving in complex environments and may not emphasize its use and tools in early stage innovation and venture creation.

ST in Healthcare takes a more practical approach to ST, by identifying areas of improvement within a given system and suggesting opportunities for innovation. The promise of many programs is to use ST to evaluate existing knowledge and resources relevant to a particular health systems issue, plan and execute an innovative solution to address the issue at hand, evaluate the outcomes of the implementation, and present the solution to key stakeholders in the host organization engaged in personal self-evaluation and critical reflection [30]. More importantly, the programs promise to deliver "applications of ethical theory to health reform, systems approach to health programming planning and evaluation, international comparison of health systems, and an in-depth investigation of health sector subsystems or building blocks" [27]. These claims highlight the relevance of ST in the early stages of innovation in start-ups and provide evidence for ST's use in complex environments that include innovation and venture creation.

Environment and Sustainability programs make use of ST and its tools by exploring the positive and negative feedback loops, relationship maps, developing skills to understand the complexity within systems, and applying a systems approach to understand the societal challenges of what?[36]. The deliverables of the courses include critical concepts about how ecosystems work, examining threats and solutions to current environmental challenges, and the effects of carbon cycles in urban ecosystems and climate change [37,38].

The two engineering courses taught learners to approach wicked problems through a ST lens, with the intention of developing critical thinking and testing understanding of the problems. The deliverables of the courses revolve around the problem-definition stage and how one could use ST to understand the dynamics of the problem at hand [39,40].

Distribution of the "Levels" of offerings (Graduate, Continuing education)

As displayed in Figure 4, Systems Thinking programs were provided to students at both graduate and bachelor's level. A total of 28 programs were exclusively targeted towards graduate students, with another 13 targeting bachelor students. Only two programs were offered to both graduate and bachelor's students.

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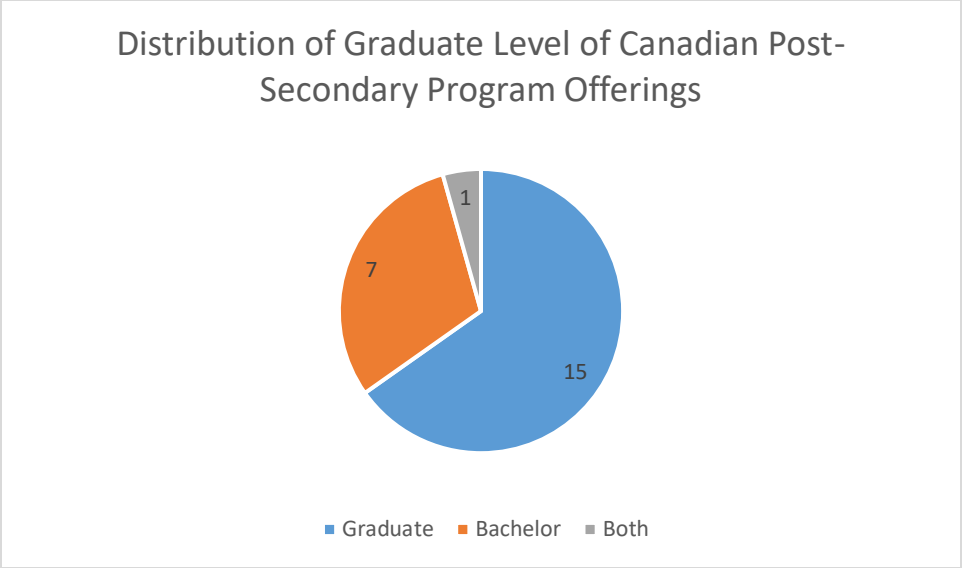

Figure 4. The distribution of Level of ST programs offered at Canadian Post-Secondary Institutes

Discussion

The detailed analysis of the programs focusing on Systems Thinking in Canada demonstrates that ST is not a topic widely discussed, although it has applications in various topics. Currently, ST instruction at Canadian post-secondary institutes are primarily at the graduate level – both in terms of the number and the comprehensiveness of the programs, suggesting that there is an assumption that learners should learn about ST in later stages of their education journey, as some of the concepts of ST could be more complex to grasp. However, one could argue that ST could be simplified and taught to learners at an earlier stage to familiarize them with learning and thinking in systems from an earlier stage of their lives. Researchers have worked towards incorporating ST concepts across various years of the K12 education and some going beyond to preschool. A recent review by the Waters Center for Systems Thinking reported that 80% of high school students and 64% of middle school students found systems thinking concepts and tools to be an effective way to learn class material [41].

More specifically, systems thinking instruction appears to be less prevalent in engineering than in other fields. Engineering as a field could greatly benefit from the incorporation of ST into its education system. Godfrey et al. emphasize this value by discussing the benefits of incorporating concepts of ST into the engineering curriculum to promote critical thinking, problem-solving, and creativity among engineering students [42]. Applications of ST have been discussed to enhance students' learning power, which refers to their ability to learn independently and adapt to changing situations. More courses in various topics of engineering must include ST as a main theme in familiarizing engineering students with specific problem areas in their field or the general field of engineering which could lead to a shift towards a more holistic, systems-based approach to engineering education.

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Godfrey argues that integration of ST in learning and teaching should occur with the aim of achieving competence rather than to acquiring specialized subject knowledge [42]. In engineering, this approach would start with a particular problem, followed by articulation of systems architecture, and a holistic view of that problem area which leads to a product which is a unique application of knowledge for a particular engineering purpose. This is similar approach taken across the ST programs and courses delivered in Canadian post-secondary institutions, which direct learners towards becoming familiar with problems in their specific area of practice. This approach provides additional learning outside of the courses that provide specialized subject knowledge in each field, further developing the learners' ability to problem solve.

Moreover, the integration of ST in the engineering curriculum would allow for the familiarization of students with the main stakeholders in a specific field, their understandings and requirements and their roles in the specific sector. More courses should integrate ST in their curriculum to allow students to explore and become familiar with sector-specific stakeholders and how they interact together.

An additional implication of ST in engineering education focuses on engineering entrepreneurship education. There are no courses or programs explicitly discussing the use of ST in engineering entrepreneurship education. ST has been emerging in business and entrepreneurial teachings in various fields, bringing focus on the impacts of business decisions on the overall landscape of business, product life cycles and sustainability. Researchers have argued for a practice-based pedagogy that combines perspectives from entrepreneurship and systems thinking. Lunch et al. argue that this method could work as a catalyst for bringing local changes in business models by making the business case go beyond the individual organization and seeing entrepreneurship as being about creating more sustainable business systems [43]. The application of ST in business school is primarily focused on this notion and ties in concepts of sustainability and equity into the business models.

The notion of sustainable entrepreneurship in engineering business context relies on the notion that entrepreneurship contributes to environmental, social, and economic development [44]. However, most engineering entrepreneurship programs are more focused on the mechanical aspects of business and do not look at its systematic implications [45]. The application of ST in engineering entrepreneurial courses could provide a new perspective and tool that could allow engineers to have a broader perspective on the application of their work.

Scholars have combined the concepts of ST and entrepreneurship outside of engineering. Lynch et al. evaluated the effect of implementing ST in entrepreneurial teaching in the context of sustainability [23]. Through a case study assessment, it was observed that none of the students solely focused on maximizing the profit, but rather considered generating value across multiple business organizations. The same teaching could be applied towards engineering entrepreneurial teaching to help with problem identification and optimizing solutions to a focus on maximizing the benefit for the business ecosystem. This could be applied to various concepts such as sustainability, health care, technology, or any other sector of interest.

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Limitations

This study was limited by the method for gathering the data and terminology used to describe the ST material included in the courses. There could be other programs that include ST concepts or tools which are not included in this review as they had not explicitly mentioned these concepts in their syllabus or learning outcomes of the program. Additionally, some programs might not have labelled the concepts they teach as "Systems Thinking" specifically and used other terms such as "System Mapping" or referenced specific tools used in ST with slight variations of their specific fields. This limitation could be addressed in the next stages of this study through reaching out to various post-secondary institutes and inquiring about their ST related programs.

Other limitations might include ST teachings which do not fall into one of the main categories of degree, course, certification or minor. This includes online resources, co-curricular workshops or information sessions about ST which could be part of the ST teaching but not a main category to be considered in this review.

Conclusion

This article highlights the importance of entrepreneurship in a country's development and looks at the ways education has been helping to promote entrepreneurship in different economies. A literature review of Systems Thinking was conducted and its relation to Entrepreneurship was discussed and definitions and frameworks in which ST has been related to Entrepreneurship and Business Development was briefly reviewed.

A scan of Canadian post-secondary programs was conducted with the goal of looking for evidence of ST instruction. A total of 24 examples of ST instruction were found, distributed across courses, minors, and certificates. Most of the ST material was offered as a standalone course and in the Health Sciences, Environmental Sciences and Business departments. The teaching of each of these fields varied and focused on certain use of ST and its tools.

ST currently appears to be underrepresented in engineering education. There is an opportunity for educators to incorporate ST into engineering programs, and engineering entrepreneurship programs more specifically, to help students with complex problem solving and enable a multidisciplinary approach.

Future research suggestions are to gather more examples of ST in engineering education from beyond Canada and to create workshops on ST for entrepreneurial engineering teams to assess their problem-solving abilities, before and after being exposed to ST. This could be a great step towards verifying ST and its effects in problem solving in entrepreneurship.

References

[1] Acs, Z. J., & Szerb, L. (2007). Entrepreneurship, economic growth and public policy. Small Business Economics, 28(2), 109-122.

© American Society for Engineering Education, 2016

[2] https://www.canada.ca/en/innovation-science-economic-development/services/small-businesses.html

[3] Schumpeter, Joseph A., and Archibald J. Nichol. "Robinson's economics of imperfect competition." *Journal of political economy* 42, no. 2 (1934): 249-259.

[4] Lerner, Josh, and Antoinette Schoar. "Does legal enforcement affect financial transactions? The contractual channel in private equity." *The Quarterly Journal of Economics* 120, no. 1 (2005): 223-246.

[5] Kelley, D. J., Singer, S., & Herrington, M. (2015). Global entrepreneurship monitor 2014 global report. Global Entrepreneurship Research Association.

[6] Audretsch, D. B. (2015). Everything in its place: Entrepreneurship and the strategic management of cities, regions, and states. Oxford University Press.

[7] Government of Canada invests over $14 million to create jobs and grow economy across Greater Toronto Area - Canada.ca, https://www.canada.ca/en/economic-development-southern-ontario/news/2023/01/government-of-canada-invests-over-14-million-to-create-jobs-and-grow-economy-across-greater-toronto-area.html, Accessed: 2023-02-26

[8] Promoting Innovation and Entrepreneurship as part of an Engineering Curriculum, Asad Azemi, Pennsylvania State University, Brandywine Campus, Media, USA

[9] Top Universities in Canada 2021 | Top Universities, https://www.topuniversities.com/university-rankings-articles/world-university-rankings/top-universities-canada-2021, Accessed: 2023-02-13

[10] Cox, Donna Hardy, and C. Carney Strange. *Achieving student success: Effective student services in Canadian higher education*. McGill-Queen's Press-MQUP, 2010.

[11] 150 ACCELERATORS AND INCUBATORS IN CANADA | by Cemre Kalender | Mentornity Blog, https://blog.mentornity.com/150-accelerators-and-incubators-in-canada-6111e89e2fd8, Accessed: 2023-02-26

[12] King, N. and A. Ross (2004) 'Professional Identities and Interprofessional Relations: Evaluation of Collaborative Community Schemes', Social Work in Health Care 38(2): 51–72.

[13] Dawson, Billy. "Bertalanffy Revisited: Operationalizing A General Systems Theory Based Business Model Through General Systems Thinking, Modeling, And Practice." Proceedings of the 51st Annual Meeting of the ISSS-2007, Tokyo, Japan. 2007.

[14] Stroh, David Peter. *Systems thinking for social change: A practical guide to solving complex problems, avoiding unintended consequences, and achieving lasting results*. Chelsea Green Publishing, 2015.

[15] Monat, Jamie P., and Thomas F. Gannon. "What is systems thinking? A review of selected literature plus recommendations." American Journal of Systems Science 4, no. 1 (2015): 11-26.

© American Society for Engineering Education, 2016

[16] Suryani, Erma, Rully Agus Hendrawan, Philip Faster Eka Adipraja, Basuki Widodo, Ulfa Emi Rahmawati, and Shuo-Yan Chou. "Dynamic scenario to mitigate carbon emissions of transportation system: A system thinking approach." *Procedia Computer Science* 197 (2022): 635-641

[17] University Accelerators, https://www.metabeta.com/blog/university-accelerators/#:~:text=A%20university%20accelerator%20is%20a,needed%20experience%20in%20this%20field, Accessed: 2023-04-03

[18] Bessant, John, and Joe Tidd. Innovation and entrepreneurship. John Wiley & Sons, 2007.

[19] Sterman, J. D. (2000). Business dynamics: systems thinking and modeling for a complex world. McGraw-Hill Education.

[20] Senge, P. M. (1990). The fifth discipline: The art and practice of the learning organization. Doubleday/Currency.

[21] Halecker, Bastian and Hartmann, Matthias, How Can Systems Thinking Add Value to Business Model Innovation? (June 16, 2013). XXIV ISPIM Conference – Innovating in Global Markets: Challenges for Sustainable Growth in Helsinki, Finland on 16-19 June 2013, Available at SSRN: https://ssrn.com/abstract=2312377

[22] Contribution of systems thinking to business model research and business model innovation Bastian Halecker, Matthias Hartmann, International Journal of Technology Intelligence and Planning, 9, 4, 2013

[23] Lynch, M.; Andersson, G.; Johansen, F.R. Merging Systems Thinking with Entrepreneurship: Shifting Students' Mindsets towards Crafting a More Sustainable Future. Sustainability 2021, 13, 4946. https://doi.org/10.3390/su13094946

[24] Jackson, T. (2016). Prosperity without growth: Foundations for the economy of tomorrow. Routledge.

[25] Jelenc, Lara, and John Pisapia. "Building bridges between entrepreneurship and strategic thinking." *Neostrategic management: an international perspective on trends and challenges* (2016): 75-93

[26] QS Ranking 2022 - Canada - Results | UniversityRankings.ch, https://www.universityrankings.ch/results/QS/2022?ranking=QS&year=2022&region=&q=Canada, Accessed: 2023-02-13

[27] Systems Innovation Capstone Project - Institute of Health Policy, Management and Evaluation, https://ihpme.utoronto.ca/course/had2040y/?highlight=systems%20thinking, Accessed: 2023-02-13

[28] INFO 4620 - Systems Thinking and Changemaking Studio - Acalog ACMS™, https://catalog.mtroyal.ca/preview_course_nopop.php?catoid=17&coid=30732, Accessed: 2023-02-13

© American Society for Engineering Education, 2016

[29] Map the System - Social Innovation - Toronto Metropolitan University, https://www.torontomu.ca/social-innovation/initiatives/programs/map-the-system/, Accessed: 2023-02-13

[30] Beyond Sustainability: Radical Transformation Through System Thinking – UNESCO Chair, https://brocku.ca/unesco-chair/beyond-sustainability-radical-transformation-through-system-thinking/, Accessed: 2023-02-13

[31] Lassonde Edge - Lassonde School of Engineering, https://start.lassonde.yorku.ca/edge/, Accessed: 2023-02-13

[32] Systems Design Engineering | Undergraduate Programs | University of Waterloo, https://uwaterloo.ca/future-students/programs/systems-design-engineering, Accessed: 2023-02-26

[33] Decision Sciences - MacEwan University, https://www.macewan.ca/academics/academic-departments/decision-sciences/, Accessed: 2023-02-12

[34] BUS 608 Systems Thinking: Creative Solutions to Complex Problems | University of Calgary Continuing Education, https://conted.ucalgary.ca/search/publicCourseSearchDetails.do?method=load&courseId=21520595, Accessed: 2023-02-12

[35 Sun D, Hyland P, Cui H. A Designed Framework for Delivering Systems Thinking Skills to Small Business Managers. Systems. 2014; 2(3):297-312. https://doi.org/10.3390/systems2030297

[36] Systems Thinking and Analysis in Health Program Planning and Evaluation | Graduate Studies Academic Calendar - SPRING 2018 (ARCHIVE) | University of Waterloo, https://uwaterloo.ca/graduate-studies-academic-calendar/archive-spring-2018/node/7392, Accessed: 2023-02-12

[37] Systems Thinking, https://serc.carleton.edu/integrate/teaching_materials/syst_thinking/index.html, Accessed: 2023-02-12

[38] Wicked Problems - Concordia University, https://www.concordia.ca/about/sustainability/study-teach/wicked-problems-mooc.html, Accessed: 2023-02-12

[39] InTeGrate, https://www.concordia.ca/about/sustainability/study-teach/wicked-problems-mooc.html, Accessed: 2023-02-12

[40] Undergraduate Courses - Troost Institute for Leadership Education in Engineering, https://ilead.engineering.utoronto.ca/academic-courses/undergraduate-courses/, Accessed: 2023-02-12

© American Society for Engineering Education, 2016

[41] Waters Foundation. (2010). The Impact of the Systems Thinking in Schools Project: 20 Years of Research, Development and Dissemination.

[42] Godfrey, P., Crick, R. D., & Huang, S. (2014). Systems thinking, systems design and learning power in engineering education. International Journal of Engineering Education.

[43] Lynch, M., Andersson, G., & Johansen, F. R. (2021). Merging systems thinking with entrepreneurship: shifting students' mindsets towards crafting a more sustainable future. Sustainability, 13(9), 4946.

[44] Haldar, S. Towards a conceptual understanding of sustainability-driven entrepreneurship. Corp. Soc. Responsib. Environ. Manag. 2019, 26, 1157–1170.

[45] Von Bertalanffy, L. The meaning of general system theory. In General System Theory: Foundations, Development, Applications; Braziller: New York, NY, USA, 1973; pp. 30–53.

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