ADAPTING ENTREPRENEURSHIP TECHNIQUES FOR CREATIVE TECHNICAL COURSE DESIGN

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ABSTRACT

Innovation and creative capacity are integral skills for the development and training of engineering graduates. Traditionally, creativity is predominant in design-based courses, rather than technical engineering or science courses, despite the need for students to apply creative problem-solving to technical challenges. This paper describes the development of a course design architecture for designing technical postsecondary courses with embedded learning outcomes in creative thinking. The proposed framework adapts techniques traditionally used in entrepreneurship and business development and considers how they may be used to address the CDIO standards in both course and curricula design. This work includes the CDIO-informed adaptation of an innovation toolkit model for post-secondary course design, considering how elements such as customers, team members, value proposition, and product offering have similar parallels to post-secondary education. The use of a structured course design architecture for teaching creativity within technical courses allows instructors to consider the educational needs of students and industry. The proposed framework adapts a mapping tool used for entrepreneurial product development, requiring course designers to consider the outcomes for their intended users, the strengths of their team, the goals of their course, and the potential pains or gains of their course offering. These planning aspects complement the CDIO standards, in particular the identification of CDIO context, planning of learning outcomes, integrating across curricula concepts, and designing and implementing learning experiences. The results of two implementation case studies are described in the context of electrical and software engineering education. The first case study is a fourth-year technical elective in designing algorithms. The second case study is a first-year computing course. Both courses showed higher levels of engagement and better learning outcomes after the implementation of the proposed changes. Results demonstrate how courses can be improved through this entrepreneurship planning model to include more creativity, application, and innovation, while adding value to technical courses without impacting the required domain knowledge learning.

KEYWORDS

Curriculum design, course design, change, creativity, framework, Standards: 2, 3, 7, 9, 12

INTRODUCTION

Innovation and creative capacity are integral skills for the development of engineering graduate attributes. As graduates face new and increasingly interdisciplinary world challenges, curriculum designers must adapt and develop courses that teach technical domain knowledge as well as expanding student creative capacity (Kelly, 2016; Atwood & Pretz, 2016; Genco, Holtta-Otto & Seepersad, 2012). Leading companies such as Google, Intel, and Microsoft are even investing their own resources in educational development in an attempt to cultivate future engineers capable of integrating technical knowledge and critical thinking in creative applications (Google, 2023; Intel, 2023; Microsoft, 2023).

In many engineering programs, students are expected to develop their innovation and creativity through open-ended introductory and senior design courses, while technical courses remain focused on domain knowledge. The learning outcomes of most postsecondary engineering courses are centered around technical concepts, rather than creative application and development. This is despite a growing need for postsecondary institutions to develop agile curricula capable of adapting to global changes (Brink, Carlsson, Enelund, Georgsson, Keller, Lyng, et al, 2023). While instructors may value creativity, it can be difficult to integrate effective creative thinking pedagogy within a technical course. In addition, a lack of focused change management may result in instructors encountering barriers when attempt to redesign large scale courses or integrated curricula, including challenges around workplace realities and limited collaborative culture (Taylor & Mannis, 2008).

Literature shows a clear need for creativity to be a greater focus in engineering (Felder, 1988; Charyton, Jagacinski, Merrill, Clifton & DeDios, 2011; Robinson & Azzam, 2009). This paper will describe the development of a course design architecture for designing technical postsecondary courses with embedded learning outcomes in creative thinking. The proposed framework adapts techniques traditionally used in entrepreneurship and business development and considers how they may be used to address the CDIO standards in curricula design. This study will detail the CDIO-informed adaptation and implementation of an innovation toolkit model for post-secondary course design, considering how elements such as customers, team members, value proposition, and product offering have similar parallels to post-secondary education.

BACKGROUND

The CDIO standards are built on a foundation of design, implementation, and feedback cycles. Effective adoption and implementation of the standards requires cooperation among varied levels of stakeholders, design and assessment of appropriate learning outcomes and content delivery, and continual improvement processes. Standards 2 and 3, for example, require curriculum and learning outcomes to be aligned not only at a course or program level, but also with faculty and industry stakeholder goals. Educators and administrators may find the design and implementation process overwhelming while also being faced with the change management challenges common across postsecondary institutions, such as budgetary constraints, large class sizes, lack of space, and peer or student resistance. Lack of alignment between graduate attributes and desired competencies is also an ongoing problem in engineering education (Ormazabal, Serrano, Blanco, Carazo, Aldazábal & Azasu, 2022). Considering whole-system improvement helps to support the drivers of educational change (Fullan, 2015). Dedicated planning tools allow curriculum and course designers to adequately assess potential challenges and possible solutions.

Entrepreneurial planning tools allow innovators to design and develop their ideas for products, services, and other offerings before expending valuable time and resources. Just as an entrepreneur plans their business strategy, a course designer needs to consider the stakeholders and desired outcomes of their educational initiatives. From flipped classrooms to experiential learning activities, the selection of pedagogical techniques can be overwhelming. Course designers may also be faced with institutional expectations and logistical limitations. The use of a structured course design architecture for teaching creativity within technical courses allows instructors to consider the educational needs of students and industry. While some entrepreneurship models have been used to develop the outcomes of entrepreneurial learning itself (Bruton, 2010), there remains opportunities to incorporate these concepts in engineering education, particularly for the integration of creative thinking and capacity development.

The Idea Model is a planning tool offered by the Straight Up Business Institute and provides entrepreneurs with a visual map for brainstorming, analyzing, and iterating on a cohesive business plan (Straight Up Business Institute, 2023). The map centers around three target areas: **People**, **Customer**, and **Offering**. These areas also overlap with one another to create intersections: **Distinctive Competencies** and **Value Proposition**. Figure 1 shows the original Idea Model.

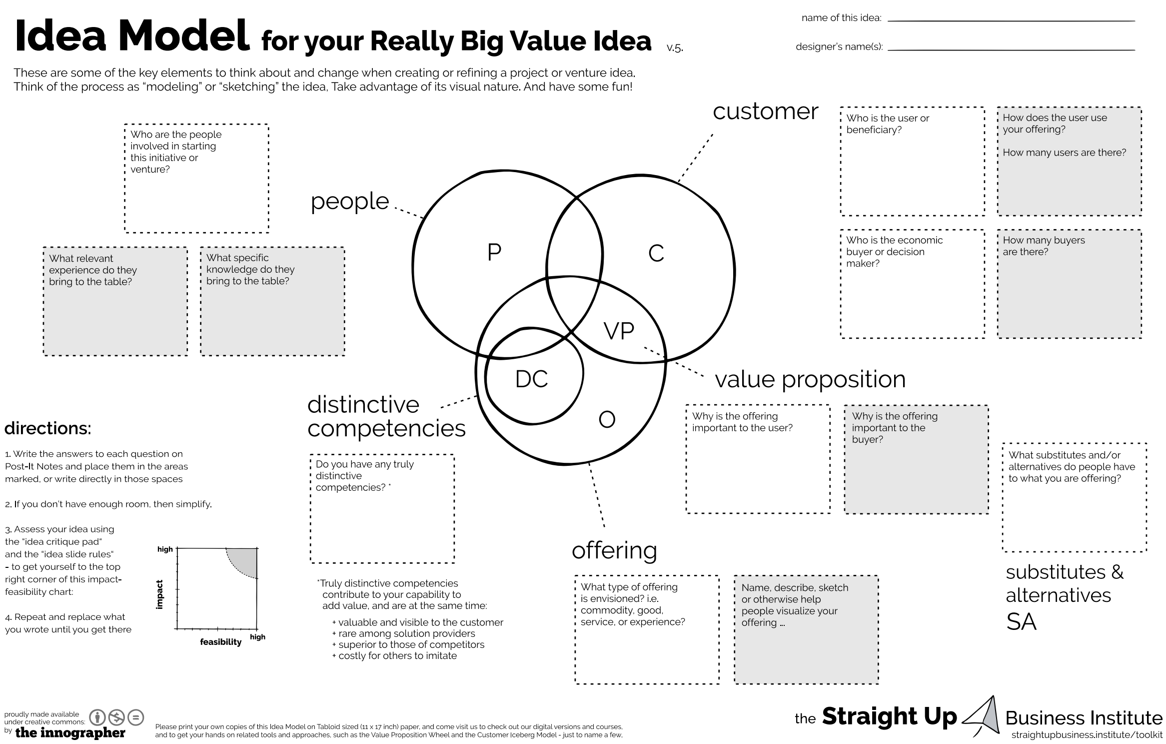

Figure 1. The Ideal Model (Straight Up Business Institute, 2023) is used for entrepreneurial planning.

The value proposition of a business requires careful consideration and balance. There are varied planning tools available to help with value proposition analysis, from financial guides to marketing maps. Strategyzer offers a simple planning tool that allows entrepreneurs to consider the potential problems and benefits of their value proposition (Strategyzer, 2023).

This Value Proposition Canvas visualization, shown in Figure 2, was used to expand on the **Value Proposition** area of the adapted framework.

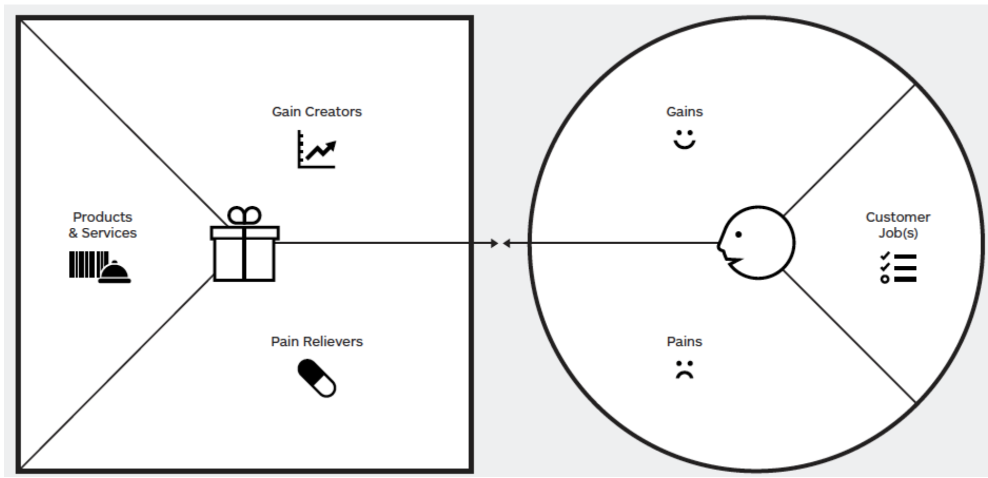

Figure 2. The Value Proposition Canvas (Strategyzer, 2023) balances the pains and gains of an idea.

METHODOLOGY

The proposed framework modifies the Idea Model and the Value Proposition Canvas from entrepreneurial planning tools into useful course or curriculum planning guides. Each section of the tools has been converted to an element that must be considered when developing pedagogy. The framework requires course designers to consider the outcomes for their intended users, the strengths of their team, the goals of their course, and the potential pains or gains of their course offering as they seek to maintain academic rigor alongside creative development. The framework adaptation map can be seen in Figure 3. The overall architecture is shown in Figure 4.

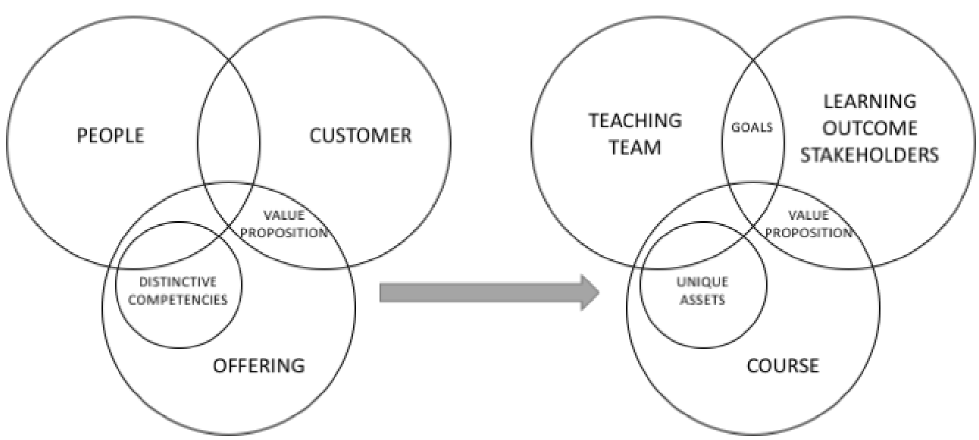

Figure 3. The Idea Model (Straight Up Business Institute, 2023) can be mapped to corresponding pedagogical areas.

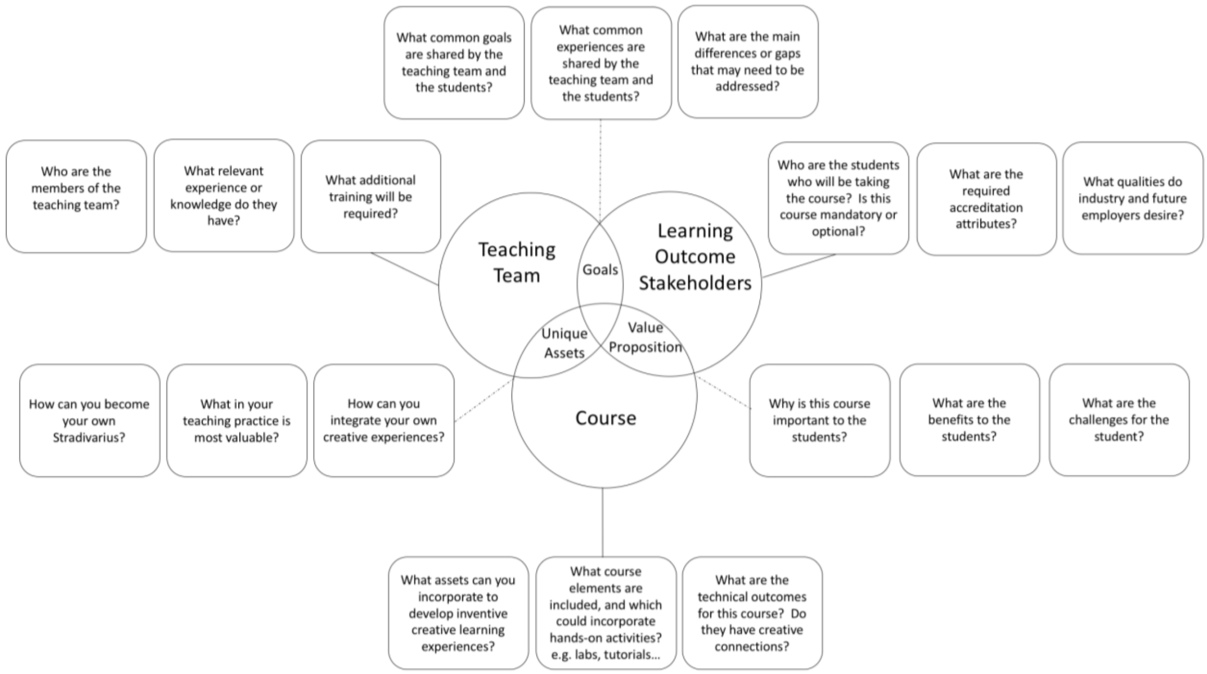

Figure 4. The adapted model allows designers to plan course and curriculum development.

The first main section, **Teaching Team**, requires a course designer to consider the **People** that will be involved in the pedagogical initiative. This may or may not include the course or curriculum designer themselves. Members of the **Teaching Team** could be instructors, teaching assistants, technicians, administrative staff, and even potentially instructors of pre-requisite and subsequent courses. The interactions between the members and their relevant knowledge or experience will help to form the course offering while determining what additional training or support may be needed.

The second main section, **Learning Outcome Stakeholders**, considers the **Customers** of a curriculum or particular course. The intended audience of a course or curriculum design is not always obvious. While students may be the initial audience, the ultimate consumers are the engineering industries that benefit from graduate employees. Decision-makers such as administration and accreditation boards also play an important role in determining educational goals and directions. Together, the target audience for educational design can be called the **Learning Outcome Stakeholders**. Other considerations may include the demographics of the student body, whether the course is a mandatory requirement, the type of available facilities, and other logistical concerns.

The third main section is the **Course** (or curriculum) that will be offered. Business leaders visualize and explain their planned product or offering. In the same way, course designers need to detail all aspects of their planned pedagogy, including the format, duration, learning environment, and types of assessment. There may be opportunities for creative integration within projects or problem-based learning, or the course content might be ideal for a flipped classroom format. Integrating creative learning outcomes with technical learning outcomes requires **Unique Assets** of both the **Teaching Team** and the **Course** to be considered. These are unique abilities and experiences that can be emphasized to create the best possible offering.

There is also some overlap between the **Teaching Team** and **Learning Outcome Stakeholders** of a course or curriculum. This intersection is where the educational **Goals** can be determined. The alignment between the **Teaching Team** and the **Learning Outcome Stakeholders** reveals common experiences and desired outcomes while uncovering disparities or potential gaps in knowledge.

Finally, the **Value Proposition** allows the designer to balance the benefits and challenges of proposed changes, novel pedagogies, or other potentially disruptive ideas. By predicting potential problems or difficulties ahead of time, course designers can attempt to mitigate the issues early in the development process. Likewise, anticipated benefits can also be enhanced during the design phase. Figure 5 shows how the Value Proposition Canvas model can be used in an educational context.

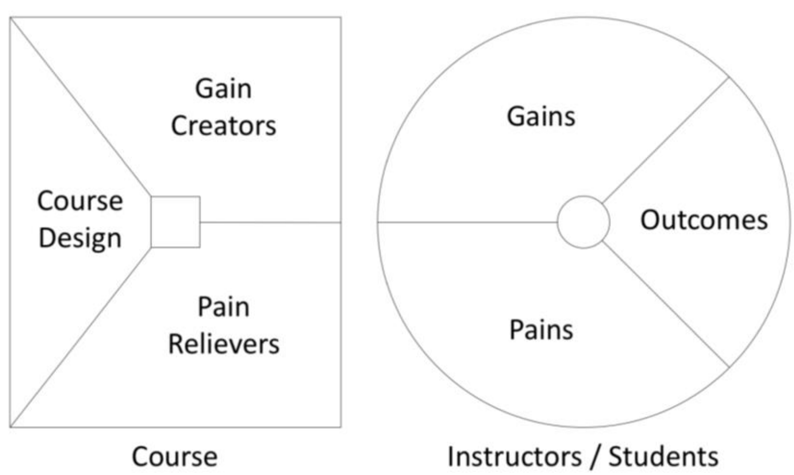

Figure 5. The Value Proposition Canvas (Strategyzer, 2023) can be applied to educational offerings.

IMPLEMENTATION

The adapted framework model has been tested with two different redesign initiatives. The first involved the design of a new creative course project for a senior electrical engineering technical course, ENCM 507. The technical material of this course taught concepts for electronic design automation and algorithms with a class enrollment of approximately 20 students. The second case study was the full redevelopment of a large-scale introductory programming class required by all first-year engineering students. The total cohort enrollment of this course, ENGG 233, was around 800 students.

Case Study #1

With a diminishing course enrollment and waning student interest, the instructor of ENCM 507 decided to implement a creative and engaging course project using game-based learning. Using the adapted framework, the instructor mapped the desired learning outcomes and available resources. She was able to identify gaps in her own knowledge of educational games and subsequently added an interdisciplinary colleague to the **Teaching Team**. Figure 6 demonstrates how the architecture was used to develop the outline of a new project. The instructor also used the Value Proposition Canvas tool, seen in Figure 7, to anticipate the potential issues of incorporating creative concepts, such as storyboarding, and logistical concerns around student discomfort.

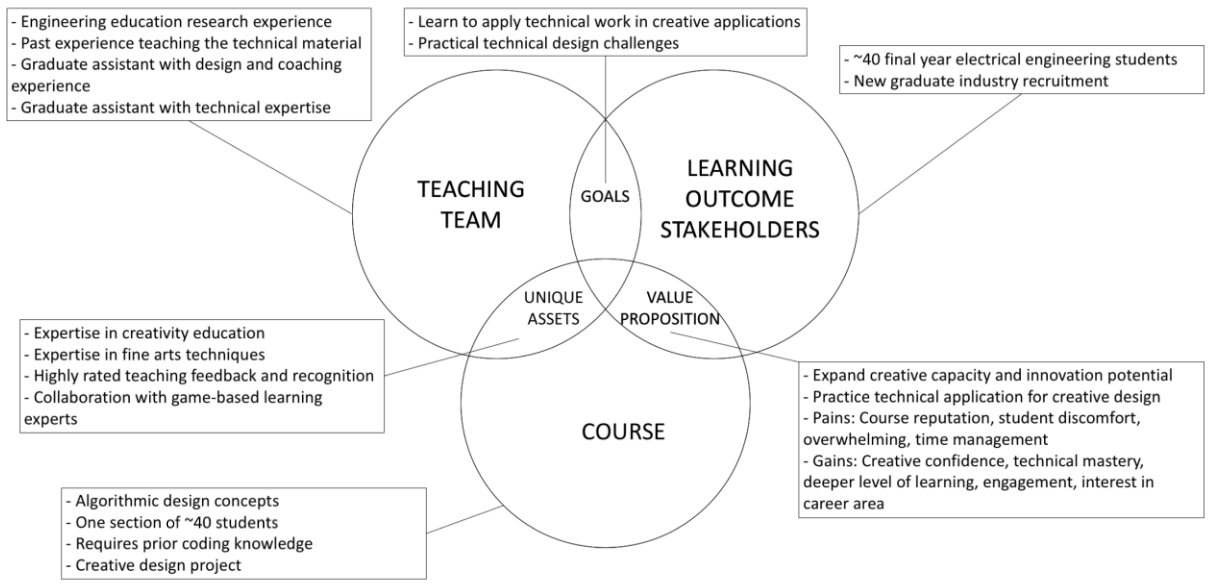

Figure 6. The course design architecture was used to develop a project for ENCM 507.

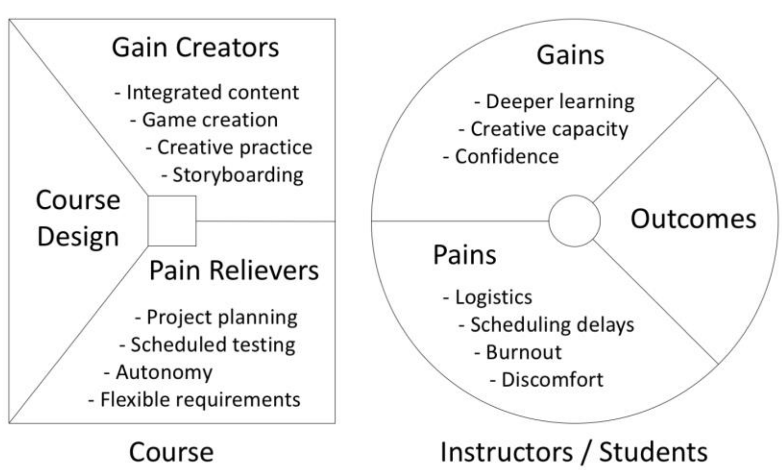

Figure 7. The value proposition of ENCM 507 balances the redesign pains and gains.

Case Study #2

Redesigning ENGG 233 was a larger process that originated from the faculty administration level. Using the framework models allowed all involved parties to better understand the overall goals and cohesive vision. The large-scale enrollment required a **Teaching Team** of two instructors, 28 graduate teaching assistants, and additional administrative support. To incorporate more experiential learning, the instructors took advantage of their **Unique Assets** (startup experience and fine arts experience). They flipped the classroom, turning the lectures into online videos and implementing a studio-inspired laboratory environment. The corresponding planning models can be seen in Figures 8 and 9.

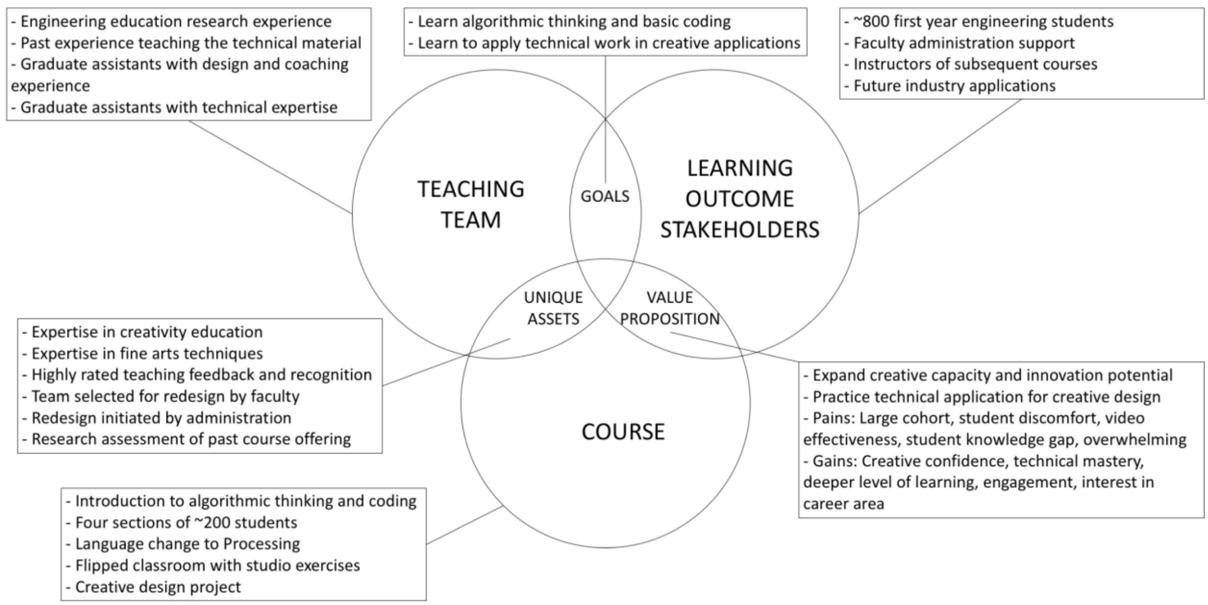

Figure 8. The course design architecture was used to redesign ENGG 233.

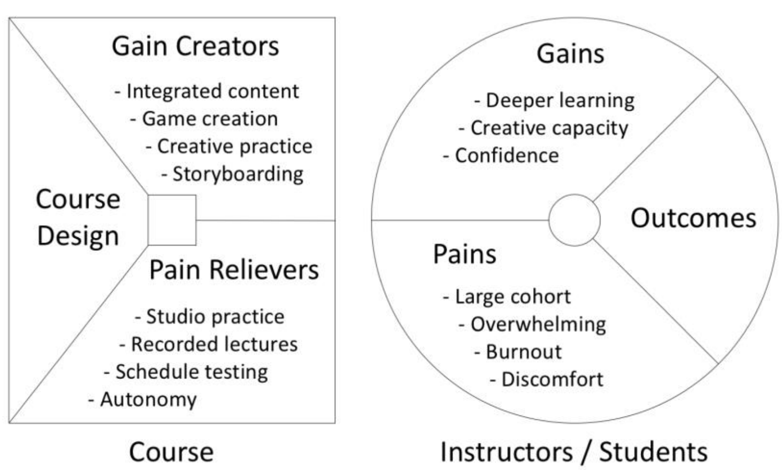

Figure 9. The value proposition of ENGG 233 balances the redesign pains and gains.

Qualitative and quantitative survey questions were conducted in each of the case studies to better understand the impact of the planning tools.

Two years after the creative project was implemented in ENCM 507, interest in the course was renewed. 40% of students in the third offering of the course said that they were motivated to enroll due to recommendations of past students and friends. 60% of enrolled students were interested in game design and 80% were also interested in the technical material. After taking the course, students expressed appreciation for the flexibility and autonomy that were implemented as "pain relievers". One student said: *"Making and demoing the video game project was the funnest project in any course I've had so far because it allowed for creative expression and problem solving."* The course instructor noticed an improvement in student performance and noted that she was able to shift her exam content from memorized concepts to open-ended design questions. Interestingly, she also reported that the project redesign revealed her own weaknesses in creativity as well.

The ENGG 233 redesign was also studied over multiple years. When compared to the previous course format, students self-reported more enjoyment of programming and improved creative thinking. Technical performance was not impacted by the changes in the course format, and instructors of the subsequent courses did not find a decline in student knowledge, preparation, or performance. The instructors felt that student learning and performance were positively impacted, and that students were able to focus more on project design within the technical course. One instructor commented on his experience with the redesign: *"It is especially important to pay attention to student needs, and carefully study the data to support your design."*

Both teaching teams continue to use the planning techniques as they iterate and refine their courses.

CONCLUSION

The developed planning framework allows educators to construct a more effective learning experience that incorporates opportunities for students to create and build on their technical knowledge. The results of two implementation case studies showed higher levels of engagement and better learning outcomes after the implementation of the mapped redesigns. The case studies demonstrate examples of how courses can be improved through entrepreneurship planning tools to include more creativity, application, and innovation without negatively impacting the required domain knowledge learning. The developed architecture is used to add value to technical engineering courses by expanding student creative capacity and enriching postsecondary engineering education.

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BIOGRAPHICAL INFORMATION

Emily Marasco is an Assistant Professor (Teaching) of software engineering and the Schulich School of Engineering Teaching Chair in Engineering Education Innovation – Digital Transformation. Her pedagogical research and teaching interests are in the areas of innovation and learning engineering, including the use of data analytics, gamification, blended learning, and entrepreneurial thinking as tools for enhancing creativity and digital literacy within software and computer engineering. Dr. Marasco's research-informed pedagogical practice integrates cross-disciplinary, entrepreneurial aspects with cognitive diversity and creative technical experiences. Dr. Marasco is active as a science communicator and outreach speaker in the local education community. She has been recognized as the 2018 ASTech Outstanding Leader of Tomorrow and as one of Calgary's 2019 Top 40 Under 40 recipients.

Laleh Behjat is a professor at the Department of Electrical and Software Engineering at the University of Calgary and the NSERC Chair for Women in Science and Engineering - Prairies. Her research focuses on developing mathematical techniques and software tools for automating the design of digital integrated circuits. Dr. Behjat acted as an academic advisor for Google Technical Development Guide and was a member of Google's Council on Computer Science Education. She is an Associate Editor of the IEEE Transactions on CAD, and ACM Transactions on Design Automation of Electronic Systems. Dr. Behjat is passionate about increasing the status of women in science, technology, engineering, and mathematics (STEM) and removing systemic barriers. Her work in diversity and education has been recognized internationally. She is currently leading a change leadership program called WISE Planet with the mission to envision and build a just, equitable, diverse, and inclusive society.

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