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A Design Curriculum with an Entrepreneurial Edge Education Promotes Enhanced Career Opportunities

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منهج تصميمي بطابع التعليم الريادي لتعزيز فرص العمل

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Abstract

This paper explores how integrating students' entrepreneurial skills, impressions, and attitudes regarding establishing a business, students' career prospects are positively impacted by the inclusion of entrepreneurship in the final-year design curriculum. Exposure to entrepreneurship heightens students' talents as well as their perspectives on entrepreneurship. Entrepreneurship education promotes enthusiasm, curiosity, and confidence, impacting students' decision-making when choosing entrepreneurship as a career route. Students who engage with creativity, design thinking, and entrepreneurial mindsets graduate with enhanced curricula and greater professional success rates. Furthermore, encouraging students to engage in entrepreneurial activities that foster positive mindsets and social behavior attitudes will help them make better career decisions and further develop their entrepreneurial tendencies, which will help them succeed in their chosen fields going forward. An entrepreneurship-focused final-year design course can significantly enhance students' ability to think outside the box and overcome the obstacles of starting their organization. By including entrepreneurial principles in design education, students can gain a broad skill set that combines design thinking, business understanding, and an entrepreneurial mindset. In keeping with the growing interest in design-led entrepreneurship, the approach places a strong emphasis on the need for multidisciplinary collaboration and the integration of numerous knowledge disciplines, including management, business, and entrepreneurship studies. By using active learning approaches and tools that emphasize teamwork, problem-solving, and creative thinking, educational institutions may foster an environment that is conducive to innovation and venture formation while also preparing their students for careers in entrepreneurship. Utilizing computational fluid dynamics (CFD) models for predictive analysis is a key component of integrating entrepreneurship into the design of laminar jet and stirred tank systems for studying CO_2 kinetics, from PhD research to commercial production. For CO_2-ionic liquid systems in stirred tanks, the design process can maximize mixing durations, energy efficiency, and flow characteristics by combining cutting-edge techniques like jet mixers and double-layer combined impellers. Furthermore. These understandings are essential for transferring processes from laboratory-scale research to industrial applications. Through the use of cutting-edge technology and computational tools, the design phase's incorporation of entrepreneurship guarantees a smooth transition from academic research to the development of commercially feasible reactors for CO_2 absorption and conversion. Ultimately, for outcomes developed during any final research stages to be successfully commercialized, it is critical to evaluate the institution's willingness to transfer technology to commercial production facilities. Researchers can effectively navigate this challenging transition by incorporating entrepreneurial education into last year's design course.

Keywords: Design Education, Entrepreneurship Education, Design-Led Entrepreneurship, Entrepreneurial Skills, Multidisciplinary Collaboration

الملخص

تسرد الورقة العلمية البحث في كيفية تأثر فرص العمل المستقبلية للطلاب بشكل إيجابي من خلال إدراج ريادة الأعمال في مناهج التصميم لآخر سنة دراسية، وذلك من خلال تنمية مهاراتهم الريادية وانطباعاتهم ومواقفهم تجاه تأسيس الأعمال التجارية. إن الترسيخ لريادة الأعمال يعزز مواهب الطلاب وكذلك وجهات نظرهم حول ريادة الأعمال. ويعزز تعليم ريادة الأعمال الحماس والفضول والثقة، مما يؤثر على اتخاذ القرارات للطلاب عند اختيار ريادة الأعمال كمسار وظيفي. يتخرج الطلاب الذين يتفاعلون مع الإبداع والتفكير التصميمي والعقلية الريادية بمناهج دراسية محسنة ومعدلات نجاح مهني أعلى. يمتلك هؤلاء المتعلمون مهارات حل المشكلات والتفكير الإبداعي والتواصل والعمل الجماعي اللازمة لريادة الأعمال. علاوة على ذلك، فإن تشجيع الطلاب على المشاركة في الأنشطة الريادية التي تعزز العقلية الإيجابية والسلوك الاجتماعي الإيجابي سيساعدهم على اتخاذ قرارات أفضل بشأن حياتهم المهنية وتطوير ميولهم الريادية بشكل أكبر، مما سيساعدهم على النجاح في المجالات التي يختارونها في المستقبل. يمكن أن يعمل مقرر التصميم لآخر عام دراسي بتركيزه على ريادة الأعمال على تحسين قدرة الطلاب بشكل كبير على التفكير خارج الصندوق والتغلب على عقبات بدء مؤسساتهم الخاصة. بما يتماشى مع الاهتمام المتزايد بريادة الأعمال التي يقودها التصميم، يركز النهج بشكل كبير على الحاجة إلى التعاون متعدد التخصصات ودمج العديد من التخصصات المعرفية، بما في ذلك الدراسات الإدارية والأعمال التجارية وريادة الأعمال. من خلال استخدام أساليب وأدوات التعلم النشط التي تركز على العمل الجماعي وحل المشكلات والتفكير الإبداعي، يمكن للمؤسسات التعليمية تعزيز بيئة مواتية للابتكار وتكوين المشاريع وفي الوقت نفسه إعداد طلابها لمهن في مجال ريادة الأعمال. يعد استخدام نماذج ديناميكا الموائع الحسابية للتحليل التنبئي عنصرًا رئيسيًا في دمج ريادة الأعمال في تصميم أنظمة النفاث الصفائحية والدبابات المقلوبة لدراسة حركية ثاني أكسيد الكربون، بدءًا من أبحاث الدكتوراه وحتى الإنتاج التجاري. بالنسبة لأنظمة السوائل الأيونية بامتصاص ثاني أكسيد الكربون في المفاعلات الكيميائية، يمكن لعملية التصميم تحسين مدد الخلط وكفاءة الطاقة وخصائص التدفق من خلال الجمع بين تقنيات متطورة مثل الخلاطات النفاثة والمراوح المزدوجة الطبقات. علاوة على ذلك، فإن هذه المفاهيم ضرورية لنقل العمليات من البحث على مستوى المختبر إلى التطبيقات الصناعية. من خلال استخدام التكنولوجيا المتطورة والأدوات الحسابية، يضمن دمج ريادة الأعمال في مرحلة التصميم انتقالًا سلسًا من البحث الأكاديمي إلى تطوير مفاعلات مجدية تجاريًا لامتصاص ثاني أكسيد الكربون وتحويله صناعيا. لنجاح تسويق المنتجات النهائية المطورة خلال أي مراحل بحثية نهائية، من الضروري تقييم استعداد المؤسسة لنقل التكنولوجيا إلى مرافق الإنتاج التجارية. يمكن للباحثين التنقل بفعالية في هذه المرحلة الانتقالية الصعبة عن طريق دمج تعليم ريادة الأعمال بمواد التصميم بالسنة الدراسية الأخيرة.

الكلمات المفتاحية: تعليم التصميم، تعليم ريادة الأعمال، ريادة الأعمال القائمة على التصميم، مهارات ريادة الأعمال، التعاون متعدد التخصصات.

1. Introduction

Engineers and technologists have historically been acknowledged as the pivotal architects of contemporary society, propelling technological advancements that fundamentally influence our modes of living, working, and social interaction. In an era where society increasingly relies on technology, the significance of engineers in sculpting the future has escalated dramatically. The choices they make, whether within the domains of infrastructure, energy, healthcare, or digital technologies, not only tackle existing issues but also establish the groundwork for subsequent advancements. These professionals are pivotal in enhancing sustainable development, confronting global challenges like climate change, and securing that future generations inherit a world that is more efficient, equitable, and habitable. The significance of engineers in shaping the future has been extensively examined in both academic and professional discourses. Grasso and Burkins (2010) assert that engineers are integral to confronting pressing challenges, including climate change, energy security, and sustainable urbanization. Their capacity for innovation is essential for devising solutions that reconcile environmental sustainability with economic progression. For example, engineers are instrumental in the advancement of renewable energy technologies, which are crucial for mitigating global carbon emissions (Markard, Raven & Truffer, 2012). As societies transition towards more sustainable energy paradigms, the imperative for engineering acumen to conceptualize, implement, and refine these systems intensifies. Beyond technological innovation, engineers are vital in guaranteeing the ethical utilization of emerging technologies. Harris, Pritchard, and Rabins (2013) contend that engineers bear a responsibility to contemplate the societal repercussions of their endeavors. The decisions made during the design and implementation of technologies—spanning from artificial intelligence to genetic engineering—entail ethical ramifications that could shape future societal norms and values. For instance, the escalating incorporation of automation within industries may precipitate job displacement, thereby necessitating that engineers account for the social costs associated with technological advancement (Ford, 2015). Also, engineers are immensely important in enhancing urban environments and their supporting structures. The future trajectory of smart cities, for instance, predominantly rests with civil and environmental engineers, who devise resilient infrastructure systems adept at enduring the stresses of urbanization, climate change, and population expansion (Abbas & Michael, 2020). Smart infrastructure encompassing efficient public transportation networks, green buildings, and sophisticated waste management strategies holds the potential to enhance the sustainability and livability of urban environments (Kylili, Fokaides, & Jimenez, 2015). The dynamic realm of digital technologies, including artificial intelligence, machine learning, and data analytics, further underscores the increasing accountability of engineers and technologists. These domains are not only revolutionizing various industries but also reshaping the functional fabric of society. Brynjolfsson and McAfee (2014) propose that engineers involved in the development of these technologies will dictate how future labor markets and economic frameworks adapt to digital transformations. Their determinations regarding algorithmic design, data privacy, and system transparency will indelibly impact the ethical and social landscape for generations to come. The future is crafted by engineers and technologists. Whether through sustainable innovations, ethical decision-making, or the crafting of resilient infrastructure, their contributions yield enduring consequences for societal advancement. The choices they make today, in relation to both technological ingenuity and ethical obligations, will profoundly shape forthcoming developments and the overarching trajectory of human civilization.

2. Employers Demand Engineers Capable of Bringing Products from Concept to Market

In the swiftly transforming global economy of today, companies are increasingly in search of engineers who not only show solid technical expertise but also possess strong business insights and adept problem-solving abilities. The escalation in demand for engineers who can proficiently transition products from conceptual stages to market availability has markedly intensified, propelled by the necessity for innovative solutions, expedited development timelines, and the capacity to adapt to fluctuating market dynamics. As technological advancements become increasingly intertwined with business operations, the scope of engineering roles has broadened, extending beyond conventional technical responsibilities to encompass tasks traditionally relegated to business professionals, including product management, market analysis, and strategic planning. Numerous studies have underscored the evolving expectations placed upon employers within the engineering sector. As articulated in a report by Graham (2018), the capacity for innovation and the application of technical expertise to address practical problems is now recognized as one of the paramount skills sought by employers. This signifies a transition from a focus solely on technical prowess to a more comprehensive skill set, wherein engineers are anticipated to operate cross-functionally, effectively bridging the divide between technical innovation and business objectives. The report further accentuates the necessity for engineers to comprehend market dynamics, consumer requirements, and the expansive business landscape to facilitate the rapid and efficient delivery of competitive products. Additionally, Cox and Sharpe (2020) assert that the increasing significance of interdisciplinary collaboration has necessitated that engineers possess not only technical proficiency but also strong communication and project management capabilities. Employers are progressively searching for professionals who can proficiently lead teams, engage with stakeholders, and render informed decisions that are congruent with business objectives. This aligns with the insights gained from research by Jones et al. (2019), which uncovered that engineers with a deep comprehension of business fundamentals, like cost-benefit analysis and supply chain management, are more prone to excel in leadership roles and support the overall success of their organizations. Moreover, the imperative for engineers to expedite the market introduction of products has emerged as a pivotal element in this transformation. Research conducted by Patel and Lee (2021) elucidates how the demand for abbreviated product life cycles and accelerated innovation processes compels engineers not only to design and develop products but also to grasp the intricacies of the commercialization process. The study highlights the criticality of agile methodologies and lean product development strategies, which empower engineers to operate efficiently while upholding quality standards and satisfying market demands. The shifting expectations of employers signify an increasing requirement for engineers who integrate technical expertise with business acumen. The proficiency to resolve problems effectively and transition products from conceptualization to market readiness has evolved into an essential criterion in contemporary engineering positions, as the demarcation between technical and business functions continues to diminish. The patterns we observe indicate that aspiring engineers need to have a diverse array of skills that extend beyond conventional engineering training to tackle the obstacles present in today's industries.

The relationship linking innovation with entrepreneurship plays a crucial role in supporting technological evolution and boosting economic progress. Innovation encompasses the systematic application of creativity and original concepts to address challenges, particularly within the spheres of engineering and technology. Conversely, entrepreneurship pertains to the conversion of these inventive concepts into market-ready products or services that achieve commercial success. While innovation is predominantly oriented towards the genesis of novel solutions, entrepreneurship is focused on the pragmatic dimensions of actualizing these innovations into lucrative business endeavors. The interaction between these two paradigms is essential for both enterprises and economies, as it significantly influences the market acceptance of newly developed products. Nonetheless, it is imperative to recognize that not all innovations possess commercial viability, and entrepreneurship is pivotal in discerning which innovative concepts are capable of flourishing within a competitive business landscape.

3. The Association within Innovation and Entrepreneurship.

The interrelationship between innovation and entrepreneurship has been extensively examined as pivotal forces in economic evolution and technological advancement. Schumpeter (1934) was among the pioneering scholars to elucidate the correlation between these two constructs, asserting that innovation constitutes the core of entrepreneurial endeavors. Schumpeter posited the concept of "creative destruction," wherein novel innovations disrupt established markets, thereby creating openings for entrepreneurs to launch ground breaking products and services. This notion has significantly shaped contemporary discussions surrounding the association between innovation and entrepreneurship. Drucker (1985) further delved into this relationship, positing that innovation serves as the quintessential tool of entrepreneurship. He underscored the responsibility of entrepreneurs to engage in systematic opportunity recognition, whether through emerging technologies, shifts in market demands, or transformations in consumer behavior. Drucker also observed that although innovation propels entrepreneurship, not every innovative concept can be effectively commercialized, thereby highlighting the critical role of market viability in the entrepreneurial framework. In a more recent investigation, Bessant and Tidd (2015) analyzed the complementary nature of innovation and entrepreneurship within the commercial sphere. They contended that innovation encompasses the creative endeavor of originality, while entrepreneurship is concerned with discerning which of these ideas possess the potential for commercial triumph. The research highlighted how crucial it is for business founders to be not just creative but also to have the insight needed to evaluate market trends, handle potential risks, and develop effective business plans to ensure their innovations succeed commercially. Yet, the persistent challenge remains that not all innovative products or concepts are viable within the marketplace. According to Gartner and associates (2017), this challenge was carefully analyzed, leading to the conclusion that innovation is a crucial element for entrepreneurship, yet it is not enough by itself. The authors emphasized that entrepreneurs must contemplate a multitude of factors, including customer requirements, market scope, production expenses, and scalability, to ascertain whether an innovative product can achieve commercial success. This reinforces the concept that, despite the inherent innovativeness of all entrepreneurs, not all innovations can be actualized into successful business ventures.

4. Incorporating Principles of Innovation and Entrepreneurship (I&E) into Engineering Education

In the context of the rapidly changing sphere of engineering and technology, there is an intensifying understanding of the essentiality of embedding innovation and entrepreneurship (I&E) strategies within engineering curricula. Engineering curricula have historically emphasized technical problem-solving competencies, frequently neglecting the significance of entrepreneurial cognition. Nonetheless, as the necessity for engineers who cannot only innovate but also actualize their concepts in the marketplace escalates, academic institutions are progressively integrating I&E frameworks within their extant programs. This pedagogical strategy aspires to furnish forthcoming engineers with a holistic skill set, thereby facilitating their success in both technical and commercial spheres. The amalgamation of these constructs within design courses affords students pragmatic exposure to the application of creativity and entrepreneurial methodologies to tangible challenges, thus preparing them to emerge as adaptable professionals capable of leading in industries driven by innovation.

The imperative for a transformation in engineering education has been extensively documented. According to Duderstadt (2008), engineering graduates need to be equipped to function within a global marketplace that prioritizes creativity and innovation in conjunction with technical proficiency. Duderstadt contended that for engineers to make significant contributions to economic and technological advancement, they must be endowed with both the cognitive orientation and the competencies requisite for entrepreneurial thought. He observed that conventional engineering education, which predominantly centers on technical problem resolution, is inadequate for preparing students to navigate the intricacies of contemporary industry, wherein business insight and market cognizance are paramount. Byers, Seelig, and Sheppard (2011) resonated with this perspective, advocating for the incorporation of entrepreneurship into engineering design curricula. They underscored that nurturing an entrepreneurial mindset among engineering students promotes innovative problem-solving and the capacity to identify and capitalize on business prospects. Their empirical research illustrated that students who are introduced to I&E concepts are more predisposed to formulate innovative solutions that are not only technically robust but also economically viable. The significance of experiential, project-centered learning was emphasized by Byers et al., indicating that students can utilize I&E principles on design problems, acquiring valuable entrepreneurial skills while refining their engineering expertise. In corroboration of these findings, Osterwalder and Pigneur (2013) proposed a systematic framework for the infusion of innovation and entrepreneurship into engineering courses, with a particular emphasis on design-centric projects. They asserted that design courses inherently align with I&E concepts, as they necessitate students to create prototypes and contemplate real-world limitations. The model put forth by Osterwalder and Pigneur underscores the necessity of instructing students on how to discern customer requirements, formulate value propositions, and construct business models in conjunction with their technical designs. This pedagogical approach guarantees that engineering students are not only proficient in devising innovative products but also possess the acumen to evaluate market viability and scalability. Moreover, Graham (2016) investigated the outcomes associated with the incorporation of I&E education into engineering curricula, concluding that students exposed to these paradigms are better equipped for the challenges inherent in today's dynamic business landscapes. His research revealed that students who participated in design courses inclusive of an entrepreneurial dimension exhibited heightened levels of creativity, risk propensity, and adaptability in comparison to their counterparts enrolled in traditional programs. Graham suggested that such competencies are critical for engineers who aim to excel in sectors characterized by innovation, wherein triumph frequently hinges on the capacity to adeptly navigate both technical and commercial challenges. Yoder and Kramer (2020) elaborated on this premise by assessing the ramifications of the integration of innovation and entrepreneurship (I&E) on the career paths of students. Their research revealed that graduates who had engaged with entrepreneurship and innovation throughout their academic journey were significantly more inclined to embark on careers within startups or entrepreneurial initiatives, indicating that the inclusion of I&E frameworks nurtures a proactive and entrepreneurial disposition. Yoder and Kramer advocated for educational institutions to persist in investigating methodologies to weave business-oriented competencies into engineering curricula, thereby enhancing the preparedness of students for an interdisciplinary workforce focused on innovation.

In response to the escalating demand for engineers capable of excelling in both technical and business domains, the amalgamation of innovation and entrepreneurship into extant design courses offers a substantial opportunity to furnish prospective engineers with a comprehensive skill set. The scholarly discourse indicates that the incorporation of I&E principles into engineering education augments students' proficiency in innovation, the identification of business prospects, and the commercialization of products. Thus, by embracing this methodology, educational programs can foster the development of engineers who are adept at technical problem-solving and also prepared to take on leadership positions in the innovation-driven industries of tomorrow.

5. Innovation and Entrepreneurship in a Design Course for Senior Engineering Students

The incorporation of innovation frameworks into the engineering curriculum for final-year students emphasizes the instruction of applying creativity in the resolution of engineering challenges. By fostering a mindset conducive to unconventional thinking, students will devise distinctive solutions to the obstacles they will encounter in their professional trajectories. The curriculum further aspires to nurture an entrepreneurial orientation by guiding students in the transformation of innovative concepts into feasible business ventures. This encompasses the assessment of the viability of their ideas and the navigation of the commercial processes requisite for the introduction of a product into the marketplace. To reinforce these theoretical perspectives, the course underscores practical engagement, allowing students to engage in hands-on projects that replicate authentic scenarios encountered in the industry.

Through these initiatives, students gain exposure to the comprehensive product development continuum, from ideation to market introduction, thereby augmenting their problem-solving capabilities and flexibility. Collaboration constitutes a pivotal aspect of the course, as it fosters teamwork to emulate real-world engineering settings where interdisciplinary teams are indispensable. This component will equip students with the ability to collaborate effectively within diverse teams, an imperative competency in both engineering and business landscapes. Ultimately, the course concentrates on the cultivation of fundamental competencies such as critical analysis, innovative problem resolution, and commercial insight. These competencies will ensure that graduates are adequately prepared to reconcile technical proficiency with strategic business acumen, thereby fulfilling the anticipations of contemporary employers.

The initial phases of entrepreneurial development are frequently characterized by substantial uncertainty and ambiguity, accompanied by an absence of definitive guidance. This state of affairs can be analogized to a design challenge, wherein solutions are not readily apparent and necessitate iterative investigation and action. In response to such challenges, an innovative educational paradigm has emerged: entrepreneurship education informed by a design methodology. This strategy aspires to equip learners with the essential competencies to adeptly navigate design challenges, thereby alleviating uncertainty inherent in the entrepreneurial journey. Fundamental to this methodology is the nurturing of "designedly" behavior, which entails engaging creatively and iteratively with multifaceted issues.

The theoretical underpinnings of this educational framework are anchored in design theory, which asserts that comprehending design challenges and participating in designedly behavior can assist students in managing the intricacies associated with initiating a new venture. Design theory underscores that problem-solving within uncertain contexts necessitates a flexible, exploratory mindset, akin to the cognitive approach requisite for entrepreneurial achievement. By promoting this paradigm among students, the educational model cultivates a capacity to iterate through prospective solutions, mirroring the iterative essence of both design and entrepreneurship. The configuration of the course and its practical ramifications are tailored to encourage students to demonstrate designedly behavior through immersive, experiential learning. The curriculum integrates real-world challenges, enabling students to engage with genuine problems and collaborate with stakeholders. This engagement not only contributes to the formulation of entrepreneurial concepts but also facilitates the practical incubation of nascent ventures. The organization of the course, which prioritizes iterative development, guarantees that students acquire a comprehensive understanding of their venture ideas, thereby preparing them to identify and pursue lucrative business prospects. In the end, the purpose of this educational framework is to empower students with the tools required to skillfully maneuver through the unpredictable terrain of entrepreneurship by nurturing a reflective, iterative approach that mirrors the hurdles faced during the creation of new ventures. The synthesis of design thinking and entrepreneurship education illustrates the vital importance of experiential learning, equipping students to engage with the complexities and pressures inherent in entrepreneurship within an ever-changing and uncertain environment.

5.1 Laminar Jet Apparatus Design & Manufacturing from Lab to Commercialized Compact Research Setup

The HTC Laminar Jet Apparatus™ was conceptualized by collaboration of Dr. Ahmed Aboudheir, who held the position of Chief Technology Officer at HTC, with Dr. Mohamed Edali, whose pivotal contributions to the design of the apparatus were vital to his doctoral research conducted at the Faculty of Engineering, University of Regina. This apparatus is based on Aboudheir's foundational design during his PhD lab work, which is articulated in various scholarly articles, and is depicted diagrammatically in drawing number HTC-LJA. Pinnacle Industrial Services executed the fabrication with Dr. Edali, who was engaged by HTC to oversee and evaluate the assembly of the apparatus in stringent compliance with the comprehensive specifications that were established and sanctioned throughout the five-year duration of Edali's PhD laboratory work on the lab setting apparatus.

The apparatus, engineered for the StatoilHydro Research Center, epitomizes a compact and commercially viable adaptation of the experimental framework employed by Edali during his doctoral research. This design setting and objective as stated in Fig. 1 is substantiated by four published scholarly articles during the five years of Edali's PhD research work and is illustrated in the mentioned schematic. The system is comprised of a constant-head liquid supply, which facilitates the gravitational delivery of an absorbing liquid through a temperature-regulated bath into a jet chamber. The constant-head mechanism guarantees a consistent liquid flow rate, with the liquid forming a downward-directed jet within a gas-absorbing environment before being collected in a capillary receiver. The gas, sourced from a pressure cylinder, may, at the discretion of the experimental protocol, be saturated with water vapor at the designated experimental temperature prior to its introduction into the absorber chamber.

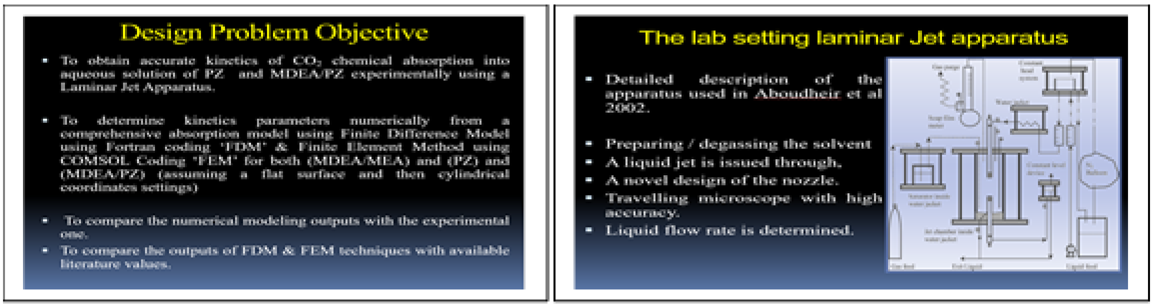

Figure 1: Entrepreneur design setting and objective to Commercialization.

A two-dimensional traveling microscope was utilized to accurately quantify the jet length during the experimental procedure as shown in Fig. 2 of the designed and ready commercial professional research setup of the Laminar Jet apparatus. The temperatures of the liquid entering and exiting the jet chamber, in addition to the gas entering both the jet chamber and the gas flow meter, were meticulously recorded. The most precise methodology for ascertaining the mass transfer rate, in terms of absorption rate, was the volumetric technique. As depicted in design drawing, upon the establishment of a stable jet flow, a gaseous stream comprising exclusively of the absorbable gas was directed through a gas heater, a CO_2 balloon, a digital flow meter, and the absorption chamber of the laminar jet apparatus. During this phase, the purge gas was systematically vented into a fume hood. The flow measurement tool utilized in the trial was calibrated to analyze flow rates varying from 0.1 to 50 cm^3/min.

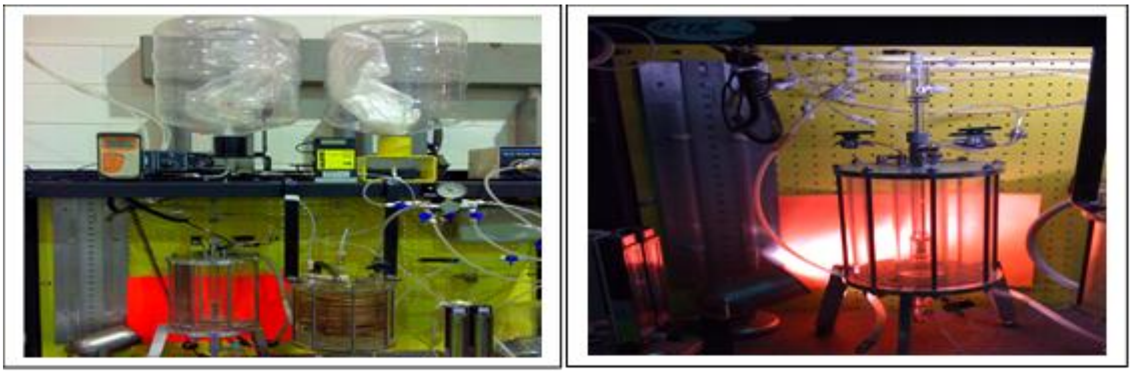

Figure 2: Designed and ready commercial professional research setup of the Laminar Jet apparatus.

Once an adequate duration had elapsed to confirm that both the CO_2 balloon and the jet chamber were adequately filled with gas, the gas feed valve and the purge tube valve were securely closed. At this juncture, the CO_2 balloon served as the exclusive gas source for the absorption process. The flow rate indicated by the digital flow meter was directly correlated to the volumetric absorption rate. An array of experiments was conducted, and the average values were subsequently compiled for analysis.
The diffusivity of CO_2 in water was quantified utilizing the HTC Laminar Jet Apparatus to corroborate the accuracy of the design. This methodology is conventionally employed for the evaluation of such apparatuses. The protocols for measuring the CO_2 absorption rate and calculating diffusivity are thoroughly documented in the design operating manual references as in Fig. 3. A notable agreement was observed between the findings of the experiments and the available diffusivity statistics, showcasing an average absolute deviation of 6.6%. This deviation remains within acceptable parameters for instances in which the gas absorption rate into a physical solution, specifically CO_2 into water, is minimal.

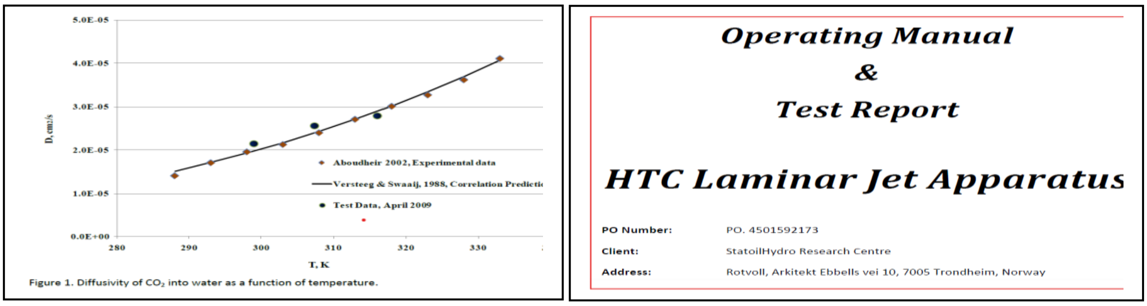

Figure 3: The design operating manual referenceing comprehensive information on determining diffusivity and the rate of CO_2 absorption.

5.2 Stirred Cell Apparatus Design & Manufacturing from Lab to Commercialized Compact Research Setup

The HTC Stirred Tank Apparatus was conceived as a result of the collaborative efforts between Dr. Ahmed Aboudheir, the Chief Technology Officer of HTC, and Dr. Mohamed Edali, whose significant contributions to the apparatus's design were pivotal to the research activities undertaken by their associate, Dr. Amr Henni, within the context of his doctoral studies at the Faculty of Engineering, University of Regina. This apparatus is predicated upon the foundational design established by Henni during his doctoral laboratory investigations, which are extensively documented in various scholarly articles and represented diagrammatically in Drawing Number HTC-STA. The construction of the apparatus was executed by Pinnacle Industrial Services, under the oversight of Dr. Edali, who was contracted by HTC to ensure that the assembly conformed strictly to the comprehensive specifications delineated during his doctoral research concerning the initial lab-scale apparatus. The final design, created for the StatoilHydro Research Center, epitomizes a compact and commercially refined iteration of the experimental arrangement utilized by Edali in the course of his doctoral research. Stirred cell reactors represent batch-operated systems characterized by their operational simplicity and the notable benefit of obviating the necessity for liquid phase analysis. Rather, the evaluation of kinetic parameters is exclusively accomplished through the observation of the pressure history of the gas phase. The fundamental elements of the HTC Stirred Cell Reactor apparatus, engineered for the StatoilHydro Research Center, are depicted schematically in Figure 4. In the course of a conventional experimental procedure, the absorbing liquid is conveyed into the stirred cell reactor via gravitational forces and permitted to achieve equilibrium until the reaction temperature reaches a stable state. The cell's temperature is maintained at a stable point by using a water bath that is temperature-controlled and linked to the reactor's cooling jacket. The absorbate gas CO_2 is sourced from a small high-pressure cylinder that is submerged in the same water bath to ensure a uniform gas temperature, thereby sustaining the requisite operating conditions.

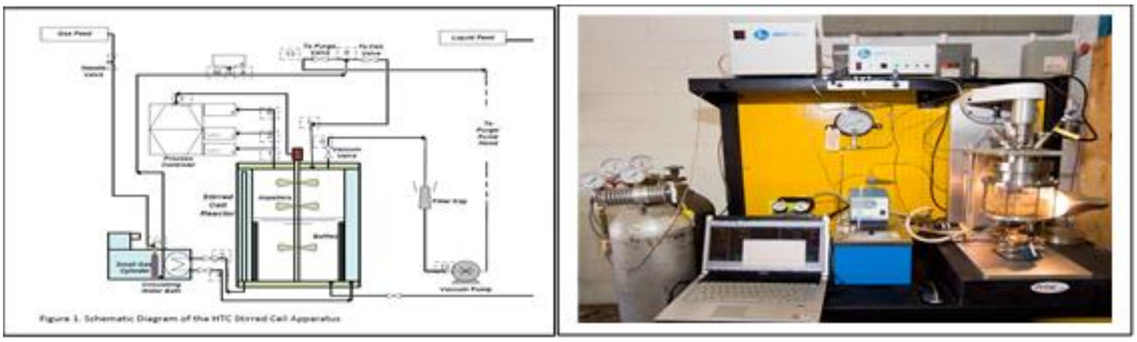

Figure 4: Designed and ready commercial professional research setup of the stirred cell apparatus.

The experimental investigations were executed utilizing a stirred cell reactor characterized by an internal diameter of 12.5 cm and an overall volume of 1890 cm³. The reactor comprises three principal components as in Fig. 4; a lower flange situated on the liquid side, an upper flange located on the gas side, and a jacketed glass tube that interconnects the two flanges. The flanges, fabricated from stainless steel, are outfitted with various instrumentation and control apparatuses, encompassing a rotary transmission lead-through, temperature sensors, a pressure transducer, as well as inlet and outlet valves for both gaseous and liquid phases. The liquid and gaseous phases are subjected to agitation via a common set of stirrer heads, which can be electronically regulated to attain the requisite rotational speed with an accuracy of ±1 rpm. To mitigate vortex formation during the stirring process and to maintain a stable, flat horizontal interface between the phases, the reactor is furnished with eight specialized baffles specifically engineered for this objective.

Conclusion

The infusion of entrepreneurial education within advanced design curricula equips researchers with the requisite competencies to adeptly navigate this pivotal transition. This methodology is indispensable for the amplification of processes transitioning from laboratory research to industrial applications. By harnessing cutting-edge technology and sophisticated computational instruments, the incorporation of entrepreneurship during the design phase guarantees a fluid trajectory from academic innovation to the establishment of commercially viable reactors for CO_2 absorption and conversion. Ultimately, the synthesis of entrepreneurial methodologies in the crafting and enhancement of laminar jet and stirred tank systems associated with CO_2 kinetics research aims to connect the realms of scholarly exploration and commercial production. For the efficacious commercialization of research findings, particularly during the concluding phases, it is imperative to evaluate institutional preparedness for the transference of technology to industrial environments.

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