Engineers, Entrepreneurs and Innovation at a Liberal Arts University

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Dr. Mick Bates is the Founding Program Chair and Associate Professor for Business Administration at Life Pacific College. As the Director of the Innovative Enterprises Program at Taylor University for 8 years, his primary charter was to imbue the spirit of innovation and entrepreneurship inside and outside of campus. Over the years he has fostered student innovation and entrepreneurship opportunities in the classroom and through a host of extracurricular activities such as a statewide business plan competition and on-campus incubator. Dr. Bates served as a board member and past executive committee member on two economic development organizations. His nearly 20-year business career revolved around high tech start-up companies in the contact center industry. His international experience includes an exchange to Guatemala during college, living in Germany for three years, business trips to various European countries, and in his time with Taylor University and Waynesburg University, research, speaking, and education travels to China, Laos, South Korea, Thailand, East and West Africa. Dr. Bates is a graduate of the United States Military Academy at West Point, holds an MBA from Regent University, and a Doctor of Management with George Fox University.

Dr. Donald Ken Takehara, Taylor University

Don Takehara was Director of the Center for Research & Innovation (CR&I) and Associate Professor at Taylor University for 9 years. With responsibility for leadership and overall success of the CR&I, Don developed/implemented an integrated program of research, entrepreneurship, and business assistance. During these years, research grant funding tripled, over 20 new companies were launched/assisted, and consultant services were provided to 100+ companies/organizations. Don also taught classes in engineering, physics, and chemistry and performed research in STEM Education (high altitude ballooning), biomass gasification, and wind turbine reliability/optimization. Previous to Taylor, Don was at Dow Corning Corporation for 16 years as a technology leader, project leader, and Expertise Center Leader in the R&D of processes and products for silicon containing materials. Don is currently a consultant for university-industry partnerships, grantsmanship, research development, partnership development, engineering, project management, and science education. Don received his PhD and MS in Chemical Engineering at Northwestern University and his BS in Chemical Engineering at Purdue University.

Dr. Hank D. Voss, Taylor University

Dr. Hank D. Voss received his Ph.D. in Electrical Engineering from University of Illinois in 1977. He then worked for Lockheed Palo Alto Research Laboratories prior to coming to Taylor University in 1994. He is currently a Professor of Engineering and Physics at Taylor University. Some of the courses that he regularly has taught include Principles of Engineering, Intro to Electronics, Statics, Advanced Electronics, Jr. Engineering Projects, FE Review, Control Systems, Fundamentals of Space Flight Systems, Astronomy, and Sr. Capstone Sequence.

He enjoys mentoring undergraduate students in aerospace, sensors, and energy-related research projects. Some of the research areas include spacecraft nano-satellite technologies, satellite payload instrumentation, High Altitude research Platform (HARP) experiments, wave particle interactions in space, space-flight X-ray imagers, construction and renewable energy engineering and architecture, and philosophy of science. Dr. Voss has worked as PI on many NASA, Air Force, Navy, NSF, and DOE research grants and has published over 120 scientific papers.
Engineers, Entrepreneurs and Innovation in Liberal Arts Universities
Introduction

Experiential learning with opportunities to ideate, create and implement with the distinct possibility of failure, appear to address the cognitive abilities of entrepreneurial mindsets better than traditional classroom lecture.\(^5\) Providing this learning environment for STEM students in the liberal arts university is challenging. Gone are the days of ivory tower universities whose scholarly work is secluded from the external world. Today, universities are called upon – even expected - to bring value to their community, their country, and the world. For instance, the Lilly Endowment recently awarded $62.7 million to 39 Indiana universities to implement programs to improve job prospects for degree holders. The Vice President for Education for Lilly Endowment emphasized the role of the university in supplying industry with qualified employees, “The Endowment has seen firsthand that colleges and universities have the ability and desire to help improve the job prospects of college graduates in Indiana, and we wanted to give them the resources to be even more strategic and ambitious,”\(^12\) This applies to even the small liberal arts schools.

Over the last eight years at Taylor University, a primarily undergraduate liberal arts university, the Center for Research and Innovation (CR&I) acted as a change agent and showed that small liberal arts schools can not only do research that impacts the world, but also leveraged that research into value-add solutions. The mission of the CR&I was to amplify the God-given talents and passions of students and faculty through innovative research, entrepreneurship and partnerships; thereby invigorating the community and impacting the world. These interdisciplinary, experiential learning opportunities led to the start-up of new companies and helped to solve new problems for existing companies/corporations. Ultimately, STEM students that worked with the CR&I graduated with résumé worthy real-world experience, were exposed to opportunities in which to exercise innovation, perhaps graduated into a new venture that leveraged their skills, and/or increased their ability to think entrepreneurially - as one with a state of mind to change the future.\(^9\) For the purposes of this paper, entrepreneurship is operationally defined as ideation, creation and implementation of solutions that could alter the future.

The CR&I was instrumental in engaging STEM students with local businesses and entrepreneurs that resulted in innovation. Specific examples include new businesses leveraging high altitude research technologies, computer engineers playing key roles in the start-up and development of new agribusiness tools, green technologies that were implemented in a new science building, and the generation of a new process for creating carbon nanotubes. Imagine, a liberal arts university generating intellectual property, economic and environmental value through engineering!

Innovation and entrepreneurship formed the cornerstone of the experiential learning infrastructure developed by the CR&I. In 2004, the Council on Competitiveness declared that innovation is what will determine America’s future in the 21\(^{st}\) Century.\(^3\) They defined innovation, “as the intersection of invention and insight, leading to the creation of social and economic value.” Innovation is concerned with creating solutions to problems that have value. It is characterized by change. Entrepreneurs leverage innovation into opportunity. They “see change as the norm and healthy. Usually they do not bring about the change themselves. But—and this defines entrepreneur and entrepreneurship—the entrepreneur always searches for change, responds to it, and exploits it as an opportunity.”\(^4\) The CR&I was designed to create the experiential learning environment such that maximum value was generated for the student,
faculty, institution and community at the intersection of these two activities – innovation and change.

The purpose of this paper is to share the experiences, challenges and outcomes of the CR&I program within the context of entrepreneurship and innovation at a primarily undergraduate, liberal arts university. The reader will understand the planning processes, learn about overcoming institutional hurdles, be exposed to relevant real-world case studies, and gain an appreciation for the value a CR&I-like program can deliver in similar environments.

Engineers and the Center for Research and Innovation

The CR&I was founded as a holistic approach to address the changing economic climate of East Central Indiana, and contribute to the State’s efforts to combat “brain drain” (keep college graduates in Indiana). The intent of the program was to create a culture of innovation within Taylor University that would extend to the regional community. The CR&I believed,

Innovation is the specific tool of entrepreneurs, the means by which they exploit change as an opportunity for a different business or a different service. It is capable of being presented as a discipline, capable of being learned, capable of being practiced. Entrepreneurs need to search purposefully for the sources of innovation, the changes and their symptoms that indicate opportunities for successful innovation. And they need to know and to apply the principles of successful innovation.

As a result, Taylor proposed a comprehensive program entitled the Promising Futures Program (PFP) under the direction of the CR&I to the Lilly Endowment to bring intentional opportunities to exercise innovation within the classroom, undergraduate research and community. With a grant from Lilly Endowment under the Initiative to Promote Opportunity Through Educational Collaborations program, the CR&I opened for business in the fall of 2004.

The goal of the CR&I was to retain more college graduates within Indiana through collaborative partnerships that engage faculty and students in action research and entrepreneurial development. The CR&I united faculty and students across science, humanities, and business programs to strengthen the area economy by incubating new ventures, expanding research capacity, increasing Indiana internships, and assisting established enterprises. The CR&I was also instrumental in establishing Grant County’s Innovative Network and enhancing collaboration with the Grant County Economic Growth Council and area businesses, governments, and colleges.

As originally conceived, the CR&I was composed of three divisions: Research Training Program, Indiana Pathways Program (internships), and Innovative Enterprise Program. The Promising Futures Program objectives included expanding and enhancing student-focused research training, linking students to Indiana employment, and preparing students to establish and assist enterprises. To further refine the CR&I focus on innovation and entrepreneurship, the Indiana Pathways Program was shortly transitioned to the Career Development group under the direction of Student Development.

For a small, primarily liberal arts university, the number of areas of innovation to be addressed by the CR&I were considerable. Of the 40 or so other public and private universities included as
part of the Initiative to Promote Opportunity Through Educational Collaborations program, only Taylor University’s CR&I was integrating classroom, research, entrepreneurship and the local community. The vision and mission were:

**Vision:** Students and faculty are energized through innovative research and entrepreneurship with this energy being contagious to the local community, the state of Indiana and the world.

**Mission:** The CR&I, a Christ-centered organization, amplifies the God-given talents and passions of students and faculty through innovative research, entrepreneurship and partnerships; thereby invigorating the community and impacting the world.

The vision, mission and business plan laid a foundation for the CR&I to implement the Promising Futures Program and established a center to impact students first, then Indiana, and finally the world. At the core of the CR&I was the coupling of classroom knowledge with world-class, real-life experiences for students within an atmosphere of innovation. This resulted in a unique and powerful learning environment to prepare students for the increasingly high expectations in today’s world. While one of the PFP objectives was to retain college graduates within Indiana, Taylor students were afforded the ability to impact the local Indiana community while engaged in these real life experiences. The diagram below shows how the CR&I catalyzes students and faculty:
The CR&I organizational structure, objectives, expected impact and relevance to Indiana are shown below:

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**CR&I Program Summary**

**Objectives, Solutions, and Indiana Relevance**

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<thead>
<tr>
<th>Research Training Program (RTP)</th>
<th>Interdisciplinary Enterprises Program (IEP)</th>
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<tr>
<td>Objective: To expand and enhance faculty and student-focused research</td>
<td>Objective: To prepare students to establish and assist enterprises</td>
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<tr>
<th>Science (SRTP)</th>
<th>Humanities (HRTP)</th>
<th>New Ventures</th>
<th>Business Assistance</th>
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<tr>
<th>Innovation Education Solutions</th>
<th>Indiana Relevance</th>
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<tbody>
<tr>
<td>Build new research and innovation capability by providing faculty and student training in research and business opportunities</td>
<td>National publications and grant funding build Indiana reputation, greater retention, &amp; preparedness of graduates. More productive &amp; informed faculty/students build an innovative culture.</td>
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<tr>
<td>Build Grant County Innovative Network</td>
<td>Indiana benefits greatly if universities, businesses, and governments work together</td>
</tr>
<tr>
<td>Replicate CR&amp;I components for use at other small universities</td>
<td>Jump-start innovation and retention at many small colleges, multiplying impact.</td>
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<tr>
<th>Business Stimulation Solutions</th>
<th>Indiana Relevance</th>
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<tr>
<td>Connect students with Indiana employment</td>
<td>Retain students &amp; stimulate existing companies with new ideas, research, &amp; human capital</td>
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<tr>
<td>Develop faculty/student consulting expertise</td>
<td>Improve competitive edge for Indiana companies</td>
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<tr>
<td>Create new business start-ups that give bright students the best career choices</td>
<td>Innovative new companies will retain college graduates and build economic base/human capital.</td>
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The staffing of the CR&I was built with the intention to leverage skills and talents inside and outside the classroom. Consequently, all CR&I staff with the exception of one was part-time.

- Center for Research & Innovation Director – Doctorate in Chemical Engineering, 50% teaching and 50% CR&I
- Innovative Enterprise Program Director – Doctor of Management, 50% teaching and 50% CR&I
- Science Research Training Program Director – Doctorate in Electrical Engineering, 75% teaching and 25% CR&I
- Chief Scientist – Doctorate in Physics, 90% teaching and 10% CR&I
Humanities Research Training Program Director – Doctorate in Psychology, 80% teaching and 20% CR&I

Administrative Manager – Master of Business Administration, 100% CR&I

Research Engineer – 50% engineering lab support and 50% CR&I

The CR&I provided the personnel, processes, facilities, and funding to support the program and activities associated with the CR&I’s integration of research, entrepreneurship, and business assistance. A chart showing the CR&I structure is below.

As seen in the Student Impact section below, the strong link with the classroom proved advantageous for identifying opportunities, teaching innovation to students, and creating/maintaining links with other faculty.

The Science Research Training Program (SRTP) provided faculty with grant proposal writing assistance as well as funding to launch research programs. Guiding principles included: to train student researchers and in turn build strong resumes, provide world leadership in selected research areas, build international university stature, improve faculty and publications, grow CR&I and IEP business assistance, advance facilities and equipment, and global engagement. These programs facilitated opportunities for student learning in the sciences, social sciences, humanities, arts, and business. This proved to be one launch point for the integrated research-entrepreneurship-business assistance program. The SRTP has been organized into seven primary foci: Management, Facilities, Internal Research, External Research, Business Assistance,
Missions Research, and Continuous Faculty Improvement. The SRTP showed exciting growth in external research funding (about 10-fold), summer student faculty research (about 6-fold), international journal publications, and business assistance. The SRTP indirect funding from research was used to build (with students) the astronomy observatory and the Advanced Lab building, to purchase much research equipment, and to support many internal research projects. Some key faculty and institution impacts of the SRTP within the context of the CR&I to increase innovation as part of the engineering education program at Taylor University include:

- High Altitude Ballooning for Research & STEM Education – NSF grants of $218,000 and $534,000; NASA (INSGC) Grants of $48,000
- Electron Accelerator – NSF $250,000 grant (Reconfiguration of Marion General Hospital’s medical accelerator into an educational/research tool)
- Nano and Picosatellites – Air Force grants of $100,000, $15,000, and $110,000
- Stripper Well Sensors – DOE grants of $116,000 and $30,000
- Space Science Technology – NASA grants of $50,000 (Polar SEPS) and $13,000 (Image)
- Sustainable Buildings – Euler Science Complex design, Mobile Energy Lab
- Educational Assessment - Critical Thinking, High Altitude Research Platform program, Intercultural Experiences (Study Abroad, Lighthouse, Spring Break) (NSF grants, seed funding for Critical Thinking and Intercultural Experience)
- Wind Turbine Research – NASA (Indiana Space Grant Consortium) $25,000 grant
- Automated Computer Program Grading – seed funding resulting in key research for a Fulbright Scholar faculty member
- Research and development of the potential of wind energy in Indiana
- Design of a Heliosvat that captures and disperses sunlight as well as other patentable energy saving technologies in the design of Taylor University’s Science Complex
- Development of Hydrogen car technology for an entrepreneur in Indiana
- Development of a communication network of high altitude balloons across the U.S.
- Facilitation of training in High Altitude Balloon technology for other universities
- Publication of collaborative student-faculty research in peer-reviewed journals

The list above is certainly not exhaustive, but is intended to give the reader a perspective on the range of possibilities for undergraduate research at a primarily liberal arts institution. Based on the response of the Air Force, NSF, NASA, and commercial interests, undergraduates are capable of performing innovative applied research that delivers solutions that can alter the future.

The Innovative Enterprises Program, the entrepreneurial arm of the CR&I, inspires and grows student-faculty expertise, research, and innovation into financially healthy, first-class quality projects and businesses that invigorate the local community and impact the world. This was accomplished through a program that integrated new ventures, business assistance, curricular and extra curricular support for innovation and entrepreneurial activities. Major functional areas included:

- The Taylor Business Incubator enabled students, faculty, alumni, and community members to start new ventures. Services included office facilities/services, consultation, networking with funding sources, and access to labs. Representative incubator clients are discussed in the Student Impact section below.
- Consultation (work-for-hire) projects allowed students, under faculty mentoring, to solve problems for businesses for compensation.
• No-charge start-up business consulting for students, faculty and the local community.
• The Annual Taylor Business Plan Competition
  (http://www.grantcounty.com/entrepreneurship/tubizplan/tu-competition-specifics/) with
  a total prize package (cash and forgivable loans) valued at $53,000 is open to any nascent
  business that is formed in Indiana. Students have the opportunity to compete with their
  ideas, or manage the logistics of the competition. There is a special prize of $1,000 for
  the best undergraduate entry in addition to place prizes. Tiergan Technologies presented
  below, was founded and launched as a result of a second place showing in the
  competition.

While the IEP had many points of impact, opportunity creation for college graduates was a major
goal. New company starts, fresh and creative curriculum, interaction with the local business
community and additional grant dollars all contributed to this endeavor. Over the 8 years covered
in this document, the Taylor University IEP was directly a part of about two new business
startups per year, at least four student work-for-hire projects per year, and helping to improve the
general quality and activity of the regional business community. One company, MyFarms, the
winner of the 2011 Indiana Innovation Award was started by a Taylor Engineering Physics alum
that used Taylor student consultants funded by the CR&I to develop the first prototype. He
reflected on the impact of the experiential learning activities of his undergraduate experience,

I learned "where there's a will, there's a way." I have found that this basic outlook
on life is a prerequisite to becoming a successful entrepreneur, who must
challenge the status quo and beat incumbents on a shoestring budget…my time at
Taylor was saturated with creative, entrepreneurial problem solving opportunity.
These lessons undergird my current venture, MyFarms, which is going head-to-
head with agricultural giant, Monsanto.  

MyFarms has hired over 10 Taylor University engineering and business graduates directly upon
graduation. These graduates stayed in rural East Central Indiana because there was relevant
opportunity for them to use their technical and innovation skillsets.

Below is a summary of major IEP impact in addition to that mentioned above:

• **Entrepreneurship**
  o Start-up of Stratostar Systems, Inc. a company that delivers near space solutions
  o Start-up of Tiergen Technologies, Inc. that is developing a novel process to make
    carbon nanotubes. Tiergen obtained 1st place in the Evansville Business Plan
    Competition, 3rd place in the Ball State University competition, and 2nd place in
    the Taylor University competition as well as obtaining a grant from the National
    Collegiate Inventors and Innovators Alliance
  o Start-up of VBC Geophysical Exploration that has diagnostic tools for oil and gas
    wells
• **Business Assistance**
  o Assessment of state of the art ethanol production technology for Blue River
    Ethanol in New Castle
  o Development of oil and gas well control system and fluid mechanic modeling for
    Airlift Services International in Anderson.
  o Development of the Feasibility Study and Business Plan for GCINC, Grant
    County’s business incubator
Quantitative assessment of the impact of teaching Critical Thinking at Eastbrook High School
Development of a salary survey for Marion Municipal Utilities
Literature and expert review of new processing technology for Lightwave Enterprises Inc.

Programs and activities are easy to talk about, but it is the measurable impact on engineering student education that determines the value of the investment. For a number of engineering undergraduates at Taylor University, exploring and learning about innovation and entrepreneurship as they relate to their discipline was catalyzed by their experience with the CR&I. The section that follows details a number of student case studies that helps illustrate the value of the CR&I program to their overall undergraduate education, and their resulting competitiveness in the job market.

Student Impact Cases

A program or organizational structure is only as valuable as the outcomes delivered. The CR&I was established as a broad-based, holistic organization to inspire innovation and entrepreneurship among students, faculty and the institution. The focus of this paper is to describe the impact on students.

Leveraging the operational definition of entrepreneurship presented earlier - ideation, creation and implementation of solutions that could alter the future - this section addresses the results of the CR&I as they pertain to helping students discover and learn about their entrepreneurial tendencies when actively engaged in business or research projects. Undergraduate education is a collaborative process between teacher and student to help the student define or refine their life calling in accordance with their gifting, talents and passions, as well as developing competency in a specific area of knowledge or expertise. For the CR&I, this was accomplished through hands-on engagement, instruction, challenge, application and assessment. Entrepreneurial research circles appear to be bearing this out with suggestions that the creation of opportunities to ideate, create and implement with the distinct possibility of failure, appear to address the cognitive abilities of entrepreneurial mindsets better than traditional classroom lecture.\textsuperscript{3} The CR&I was the catalyst for actively engaging students in research and entrepreneurial activities that created the environment for “failure.”

Since the CR&I had responsibilities to imbue the spirit of entrepreneurship across campus in both entrepreneurial start-up companies and innovative research/projects, the results are shared in a format that addresses each type of experiential learning activity. Specific results are discussed via case studies. First, scenarios oriented around more traditional entrepreneurial start-up companies that create economic value are shared. Second, three cases are presented from undergraduate innovative research/projects that catalyzed innovation within and outside of the university. Whether students were engaged in business or research, the end game was the same, help them realize they had the ability to ideate, create and implement solutions that could alter the future.

Entrepreneurial Start-up Companies

Another perspective on the entrepreneur is this individual has the ability to create something of value where others see no value.\textsuperscript{10} The cases below effectively describe the efforts of students in
ideating, creating and/or contributing to the effort to create a value-add business where none existed before. The cases deal with software engineering, high altitude ballooning, and process engineering for the creation of carbon nanotubes.

**BloodStat** was a software product birthed in the mind of a Taylor University undergraduate who saw a way to create economic value through efficiency for the medical industry. Essentially, the product automated a labor-intensive process to match the variability of blood test results to diagnoses and recommendations, thereby saving the doctor significant time manually reviewing, analyzing and determining courses of action. While the concept was novel, the computer engineering undergraduate had no understanding of how to move this idea forward as a business.

The CR&I provided classroom engagement, business consulting, and opportunities to exercise the concept that helped the student understand the process for taking an idea to a solution that generated economic and health value. The CR&I provided a seamless link for the computer engineering student to receive business support in the form of a marketing plan generated as part of a class project. Educational value was delivered on two fronts. First, the would-be entrepreneur gained knowledge on how to convert an idea to a market reality. Second, the marketing class project team was able to experience a live business environment by executing a marketing plan for BloodStat. Ongoing business consulting helped BloodStat understand key feasibility and business planning necessities to guide product development. To help focus the student, the CR&I arranged for the student to present his concept at the Collegiate Entrepreneurs Organization ([http://www.c-e-o.org/](http://www.c-e-o.org/)) annual meeting. Even with a last minute entry and little time to prepare, BloodStat advanced to the final round of five. This intense period helped BloodStat’s founder refine and hone the market positioning of his concept.

While these activities occupied time, what real impact did they have? First, students were able to exercise their discipline in a real-world project. Second, the engineer was forced to work in an interdisciplinary environment. Third, even though the BloodStat product was abandoned within a year after graduation, the founder affirmed the value of engaging with the CR&I.

> Even more importantly than keeping BloodStat in the green, your help with my company started a chain reaction. First, it allowed me to land the software consulting job after Taylor that got me into financial services. Next, the time I spent running the business demonstrated the necessary initiative (while the financial services experience showed the alignment) to get me into University of Chicago for my MBA. In turn, that MBA was the only way into the strategy and operations consulting role I have now. … All in all, your help and BloodStat formed the cornerstone for the career I have now and the options I have going forward.  

**StratoStar** ([http://www.stratostar.net](http://www.stratostar.net)) was birthed in 2006 by Taylor University undergraduate Jason Krueger. While a business major, Krueger at one point attempted transferring to Engineering Physics but found his schedule would not accommodate the change. He did the next best thing. He founded a company to satisfy his desire to work in a technical field, but also leverage his business education and orientation toward innovations. Krueger says it best, 

> Throughout my own education, I was always a student who struggled with conventional learning methods. Lectures, books, notes... It can all get a little, well, boring. To me, nothing could ever beat those rare learning experiences when I
would use my hands and personally experience the greater theories and lessons my teachers had for me. So when a professor at Taylor University's Space and Physics Program suggested a whole new idea for giving STEM students access to Earth's upper atmosphere, I couldn't help but run with it. I listened to him describe the way his students built experiments to test their hypotheses. He told me about how fun it was to watch the balloon disappear in the sky, and to drive across the border into Ohio for recovery. He said that students all over should get the opportunity to engage scientific discovery the way his students had. It was in that exact spirit that I founded StratoStar.\footnote{11}

Initially Stratostar was founded to deliver near space solutions via high altitude ballooning. Over the last seven years, the company has morphed into a solutions provider for experiential STEM education.

StratoStar would never have been created without the CR&I to link the entrepreneurial spirit with the engineer. While the connection between Krueger and the professor occurred in the classroom, it was the CR&I that provided funding assistance for the feasibility study Krueger performed the last semester of his senior year. It was this work and his participation in the Taylor University business plan competition that led to the decision to start the company upon graduation, and ultimately the acquisition of start-up funding. As part of the on-campus business incubator, the CR&I provided the network for Krueger to hire his first employee, a Taylor University undergraduate majoring in Engineering Entrepreneurship. As far as the CR&I, Krueger shares that the greatest benefits of the CR&I incubator are the professional assistance, proximity to Taylor research, and the cost effective office space. Krueger emphasized that his relationship with the Innovative Enterprises Program Director Mick Bates, as well as his work with TU professors across disciplines, has helped him advance his business. Specifically, Krueger stated that he is never short on advice in any discipline because of the abundance of Taylor academic professionals ready to help.\footnote{15}

The impact of StratoStar on undergraduate education, particularly for aspiring engineers, is multi-faceted. The close relationship between the company and the engineering program at Taylor has provided multiple opportunities for STEM students, especially Engineering Physics and Computer Engineering, to work on challenging, real-world business projects in a start-up atmosphere. Engineering students were always under pressure to miniaturize, simplify and make the product more user friendly. Multiple class projects were built around StratoStar’s needs creating many opportunities for interdisciplinary work among business, communication, and STEM majors. Part-time work for students helped them experience first hand the successes and failures of working in a tech company. Finally, StratoStar in partnership with the University brought in over $750,000 in NSF grants for students, faculty and partners to continue developing near space technology solutions. All in all, undergraduate students were contributing their desire to alter the future with innovations that directly helped StratoStar create value. Now StratoStar is helping STEM educators all over the world.

**Tiergan Technologies** (http://www.tiergan.com/) is another great example of how the CR&I was the vehicle for taking a STEM student from the classroom to the boardroom. Tiergan Technologies was founded by Troy Tomasik, Chemistry and Business major, during his
freshman year at Taylor. The company’s intent was to create a more cost effective chemical process for producing coiled carbon nanotubes with significant structural and electrical properties. Using his initial business plan competition second place finish purse of $4,000, Troy invested in the equipment and supplies needed to start creating carbon nanotubes. With the help of the CR&I, Troy left Taylor University with over $50,000 ($30,000 in business plan competition winnings and $20,000 in grant funding from the National Collegiate Innovators and Inventors Alliance), and a repeatable process for producing the desired carbon nanotubes. Since graduation he has worked on securing an international patent with plans to license or sell the process.

The CR&I provided the environment for Tiergan to establish itself as a start-up company. This included incubator membership, dedicated lab space, consultation from chemistry and engineering faculty at Taylor University, connections to other universities with electron microscope capability, and business consulting to assist with the business, associated competitions, and planning. Additionally, the CR&I was instrumental in connecting Troy with advisors from the Mathematics and Chemistry Departments for his design of experiment (DOE) work. The interdisciplinary nature of the entrepreneurial work is evident in Troy’s comments,

> Without the assistance of [the CR&I] I would not have had the contacts and knowledge to accomplish this,” Tomasik continued. “The chemistry department has been helpful and knowledgeable. When I come across an impasse they are always quick to lend advice. It makes it more possible for an undergraduate to conduct high-end research.

While Troy was an exceptional student, the opportunities afforded to him through the CR&I impacted his outlook on entrepreneurship. First, without that very first experience the spring of his freshman year in the business plan competition, it is safe to say he never would have started Tiergan. The planning process and the $4,000 energized him to the next level. Second, the Director of the CR&I, Don Takehara recommended that Troy take on the Chemistry major to further develop the technical capabilities in pursuit of his concept. Third, the ongoing business consulting helped him generate additional start-up funding as well as navigate significant issues such as workspace, intellectual property concerns, supporting diagnostics, and the building of a network for professional services. Finally, Troy leveraged this real-world, experiential learning to secure a delayed entry acceptance into the Harvard MBA School even before he graduated, as well as a job in an environmental consulting firm in Boston. This is no small feat for a graduate from a small, liberal arts university in the Midwest. Troy continues to work the patent process for his coiled carbon nanotubes.

**Innovative Research/Projects**

Engaging undergraduate students in innovative research/projects is another avenue for students to learn about entrepreneurship, which is defined as “ideation, creation and implementation of solutions that could alter the future.” The CR&I targeted research and projects that would be indicative of what engineers would experience at companies and at graduate schools. In order to imbue the spirit of entrepreneurship in students, it is hypothesized that students need to participate in research and projects that truly inspire them to make a real difference in the world and alter the future. What follows are three examples of these type of innovative research/projects.

**Satellites**
Background: In 1994, Dr. Hank Voss came to Taylor University after being at Lockheed Martin Inc. for 15 years. He brought with him his expertise as well as NASA grants in space science technology - sensors and instruments that go on satellites to gather data on the earth’s space environment. He started engaging undergraduate students in his research and realized that undergraduates could do meaningful research in this area. Dr. Voss then expanded his research to include nanosatellites – small satellites that are more cost effective and versatile than traditional satellites. In 2002, he received a grant for students to participate in the Air Force University Nanosat program (UNP-3) in competition with 12 other universities. His students designed and built a 27 unit cubesat with a modular design to gather data on the effect of thunderstorms on near space. Most recently, Dr. Voss received a grant from NASA’s ELaNa (Educational Launch of Nanosatellites) Program to launch a nanosatellite. Students designed and built TSAT, which is scheduled to be launched in March 2014. In 2013, Dr. Voss received another grant for students to participate in the Air Force University Nanosatellite program (UNP-8). One of the students who participated in the Satellite program learned about being an entrepreneur through the program and eventually started up MyFarms a start-up company, which is going head to head against Monsanto.

Implementation: Dr. Voss has had students work on nanosatellites in classes such as Senior Capstone, Junior Engineering project, and Principles of Engineering (Sophomores). Under his supervision, students had paid internships and practicums during the summer. In all cases, Dr. Voss treated the students as engineers in a company under his supervision using his experience at Lockheed Martin as a framework. For example, during the 2012-2013 Senior Engineering Capstone, the students as part of the Air Force University Nanosatellite Program were responsible for all aspects of the project including:

- Mission Statement and Objectives
- Project Management
- Team Formation and Roles
- Statement of Work/Work Breakdown
- Timeline & Milestone Determination and Tracking
- Budget Formation and Tracking
- Requirements Definition and Management
- Design
- Testing and Validation
- Analysis
- Systems Engineering
- Procurement
- Design Reviews (Preliminary, Critical, Engineering, Final)
- Weekly Meetings with Customer (Air Force)
- Documentation (Reports and Presentations)

The coversheet for the student proposal to the Air Force for the University NanoSat Program is below. The proposal won a spot in the two year competition with nine other universities. $110,000 was received for support, student summer jobs, and materials.
Student Deliverables: Deliverables by the students are specific, measureable, and time driven. For example, below is a picture of the Senior Capstone dual cube TSAT that is scheduled to be launched in March 2014 on a Space X rocket at the Kennedy Space Center in Florida through the NASA ELaNa program. The satellite includes a new Globalstar communication link, flight processors, bus structure, power system, solar arrays, and space weather instrumentation. A plasma probe will measure electron density, electron temperature, and vehicle potential. A 3-axis magnetometer will measure the earth’s magnetic field and ultra-low frequency waves. High efficiency (25% gallium arsenide) solar cells will be used as well as an array of temperature sensors to understand heat radiation in orbit. TSAT will map out an underexplored region called the Extremely Low Earth Orbit region at 75-200 miles altitude collecting data to study the effects of ionospheric phenomena most likely caused by the plasma environment within the region. This is believed to be the first satellite designed and built in Indiana that will orbit the earth.
Science Building

Background: For over a decade, Taylor University faculty and administrators worked on making a new science building a reality. The need was obvious with an outdated building with no room for expansion (even closets were converted to offices). In 2007, a “traditional” design for a new science building was not gaining traction with donors. At that point, Dr. Hank Voss proposed an energy efficient design with alternative energy and sustainable features. Students in Dr. Voss’ Junior Engineering class worked on the design of the building with an emphasis on the sustainable and alternative energy features of the building. Key results from the students included presentations to the Taylor University Board of Trustees to “sell” the building and documentation that was used by the architects and engineers who designed the new building. As part of the 2007-2008 Engineering Senior Capstone course, students designed and built a mobile energy lab - a small insulated building on wheels – to prototype the atrium eyelid system for saving energy on the atrium windows. This system had a commercial skylight with the mirrored eyelids that could be adjusted to bring maximum sunlight through the window. During the cold nights, the eyelids could be closed to give maximum insulating capability. The Energy Lab also had a wind turbine, solar cells, and sensors to monitor illumination, temperature, and energy production. In addition, students worked on the overall design of the building including situating the atrium (connecting the new and existing building) on the north side of the existing science building to significantly reduce heat loss from this existing building. Based on the work by the students, the new $42M Euler Science Complex with 127,000 square feet of laboratory, classroom, student interaction space, and atrium opened in the Fall of 2012. The complex obtained Gold LEED certification in the Fall of 2013 and has geothermal heating/cooling, wind turbines, solar panels, a heliostat (bringing sunlight into the center of the building), an atrium, and a green roof.

Implementation: In both the 2008 Junior Engineering and 2007-2008 Senior Capstone courses, Dr. Voss treated students as engineers in a company under his supervision. Each student had
his/her own project but had to integrate the projects together as a team. The students worked on the following aspects for the design of key features of the new science complex.

- Thermal model for energy loss
- Matlab model of HVAC
- Atrium Eyelid System
- Heliostat
- Trombe Wall
- Styrofoam 3D Model of entire Science Building
- Sustainable water processing

Students were required to complete the following:

- Project Plans
- Preliminary and Critical Design Reviews
- Testing/Data Collection & Analysis
- Presentation and Final Paper for review by engineering professionals

Student Deliverables: Deliverables by the students were specific, measurable, and time driven. Details were determined by the project management and work breakdown. Below is the 3D Styrofoam model that with CAD drawings showed the entire design of the new science complex.

3D Styrofoam scaled model of the new science building designed by students and faculty used to explain the design to Taylor University leadership, potential donors, building architects and engineers.

Below is the final science complex design by the architects and engineers. Included in this final design were about 85% of the deliverables from the Junior Engineering class projects on energy savings, architectural features, and detailed building design (including internal rooms and space).
Final Gold LEED science complex design by architects and engineers, which incorporated almost all of the deliverables from student projects.

**High Altitude Ballooning**

Background: A High Altitude Balloon can send a student experiment 20 miles into Near Space where there is extreme temperature (-65 degrees C) and pressure (1% of atmospheric), high UV, high radiation from cosmic rays, varying humidity, etc. At this altitude, one can see the blackness of space above, the thin layer of atmosphere and curvature of the earth below, as well as the features of the earth and clouds below. A picture from a high altitude balloon at 85,000 ft over the Salton Sea in Southern California is shown below.

![View of Salton Sea in Southern California from a High Altitude Balloon at 85,000 ft (UC San Diego and StratoStar)](image-url)
When a balloon is outfitted with various sensors and cameras that can stream data back to earth in real time, students can do creative experiments that they develop on their own. This enables students to develop entrepreneurial characteristics that will open their minds to the realization that they can change the world and alter the future. Dr. Hank Voss at Taylor University started high altitude ballooning as a way to test sensors and instruments as part of his space science research. After seeing the great response from undergraduate students, Dr. Voss started implementing ballooning into the classroom. As a result of the great success of ballooning at Taylor University, the CR&I led the effort to obtain two grants from NSF for $750,000. This resulted in over 80 universities trained and over 30 universities implementing ballooning into STEM classes. Currently, a nation organization (Stratospheric Ballooning Association) is being started up to support those using ballooning in their STEM classes.

Implementation: Faculty at over 30 universities are developing how to implement high altitude ballooning into many different classes in engineering as well as other sciences (chemistry, biology, environmental science, physics, mathematics, education, computer science, etc.). Engineering students can develop hardware and software to increase the capability of the high altitude balloon. They can also use the balloon as a tool to test instrumentation and/or gather data for atmospheric science, space science or earth science applications. A community of faculty and support companies in ballooning has formed and is growing. This includes opportunities for new universities to start implementing ballooning into their classes. One of the support companies is StratoStar which is one of the examples in the “Entrepreneurial Start-up Companies” section of this paper.

Assessment of Innovative Research/Projects

Alumni Survey: A survey was sent to about 70 Taylor University engineering alumni who participated in at least one of the three projects described (Satellite, Science Building, High Altitude Ballooning). In order to assess the effectiveness of these projects for imbuing a spirit of entrepreneurship in students, the following question was asked. This was based on defining entrepreneurship as “ideation, creation and implementation of solutions that could alter the future.”

How well did working on the satellite/high altitude balloon/science building program help you understand that you can be part of making a significant difference in the world? (i.e. You can be part of altering the future.)

_____ 5 - Exceptionally Well (Grade = A), 4 - Very Well (Grade = B), 3 – Well (Grade = C), 2 - Not Very Well (Grade = D), 1 - Not at All (Grade = F), N – Not Sure/Does Not Apply

From 26 responses to this question, the results were as follows:
Mean – 3.8
Sample Standard Deviation – 1.1

Some key written comments from the survey are as follows:
... the opportunity to work on the project ... helped instill in me that I could tackle tough challenges and succeed, even ones that were bigger than what I thought.

... we can do anything we put our minds to, even if it seems impossible... pushing a project to completion can change someone's life.

It gave me a better perspective of what great potential we have...

Core to Taylor’s satellite program was a vision for innovation and desire to push outward the boundaries... I felt great promise and excitement for what I could contribute..., potentially meeting global communication needs that normally required large and costly satellites.

... work on cutting-edge space science as an undergraduate student excited my passions for exploring scientific frontiers and thinking about big ideas.

These results show that these three projects did very well with helping students/alumni understand that they can be a part of making a significant difference in the world and that they can be part of altering the future. That is, these projects do imbue a spirit of entrepreneurship in undergraduate engineering students.

Faculty Survey: For the High Altitude Balloon Program, 31 faculty from various higher education institutions who are implementing ballooning into their undergraduate STEM classes responded to a survey. This resulted in the following responses.

For each of the following questions, the following scaled responses were used.
1 – Strongly Disagree 2 – Moderately Disagree 3 – Mildly Disagree 4 – Mildly Agree 5 – Moderately Agree 6 – Strongly Agree

High altitude ballooning enhanced my ability to inspire students to be creative with science and technology.
Mean – 5.2
Standard Deviation – 0.72

High altitude ballooning enhanced my ability to engage students in problem solving activities that are challenging.
Mean – 5.5
Standard Deviation – 0.51

I see the value of ballooning in giving students freedom and control to take ownership of a research project.
Mean - 5.6
Standard Deviation - 0.62

High altitude ballooning has enhanced my ability to have students handle obstacles that are encountered
Mean – 5.4
Standard Deviation – 0.62

These results show that faculty who are using High Altitude Ballooning in their STEM undergraduate classes moderately to strongly believe that ballooning can help enhance students’ entrepreneurial characteristics to be creative, engage in problem solving, take ownership, and handle obstacles. This is good evidence that High Altitude Ballooning is imbuing a spirit of entrepreneurship or illustrating that students can make a significant difference in the world and alter the future.

Lessons Learned

One principle of experiential learning is to place the student in a situation where they must take initiative, manage risk as they make decisions, and ultimately be held accountable for the results. The CR&I was the purveyor of creating opportunities for experiential education with the express outcome of generating tangible results for the students, institution and community. As seen from above, results were evident in terms of applying knowledge, revenue generation, local economic development, keeping college graduates in the State of Indiana, and creating a more competitive engineering graduate. These efforts however, were not without their challenges. One ongoing challenge was the perception of the role of engineering within a liberal arts institution. Another hurdle was the disparity between the relatively low number of students enrolled in engineering compared to other disciplines and the allocation of funding. This also contributed to the relatively short-term enrollment-oriented thinking that valued students in seats over other sources of revenue. Finally, setting up the organization for success with a dedicated manager or management team. More attention to these challenges might have created a more favorable institutional climate for creating more student opportunities to alter the future.

While there is great value of the liberal arts for the engineer, liberal arts colleges might not be the best environments in which to pursue an experiential learning model with emphasis in generating applied research with economic value and/or starting new companies. Liberal arts prepares people, particularly those in professional disciplines, to engage change as reflected on by P.C. Brown,

As our spiritual certainties and the social hierarchies reflecting them become more fluid, there will be a premium put on individuals who can grasp the context of these changes, who can critically explore the limits and limitations of any practice, and who can pursue new integrations of knowledge and practice.

The liberal arts are important for engineers to be more effective in their technical arenas, but are engineers important to the liberal arts? Even in the forward thinking environment of Taylor University, there was an underlying bias or question regarding the appropriateness of an engineering program with a heavy emphasis on real world experiential learning within a liberal arts institution. This is an important consideration for any group attempting to expand applied research, learning or ‘profession’ within a liberal arts institution. The recommendation is to proactively seek out thought leaders in the humanities and arts and bring them into the concept, development and design phases of the project. Show them how a group like the CR&I can benefit their programs. In the case of Taylor University, a significant portion of the additional funds generated through the SRTP grants found their way to fund humanities and art projects.
Another somewhat related issue was the negative perception regarding the amount of effort and resources that were applied to benefitting a minority set of majors on campus. STEM and business majors comprised just over 30% of all majors. Initially, the Lilly grant funding helped overcome this perception and to the credit of the university administration, they partially sustained the CR&I through reserve funds when the three-year grant expired. This made good sense considering engineering graduates are the majority of the top 10 or 15 degrees in terms of income potential. This translates well in terms of future giving, but the key word here is, future. When institution revenue was tight however, the key metric was enrollment directly tied to the program. With no direct tie to courses, this placed the CR&I at risk since the traditional revenue model did not apply. Even though, the efforts of the CR&I were contributing to more competitive graduates and the overall quality of education, these efforts were difficult to quantify in the absence of enrollment figures. So what is the lesson learned? Programs that create environments for real-world experiential learning, should make it a priority to generate hard links to curricular activities. This can be in the form of classes or curriculum delivered and/or managed by the program. It is one thing to say that a program is favorably received by students and prospective students, and makes a difference in their college and course choices, but quite another to tell the story by numbers of students enrolled. In the case of the CR&I, there were attempts to create project-based and entrepreneurship curriculum with CR&I responsibility. If this had occurred, there would have been a metric available to more concretely evaluate the CR&I’s contribution to enrollment. This language of the institution was enrollment.

The final learning point to be shared in this paper is that of focus. The CR&I for all intents and purposes was a start-up organization in a brand new market, the liberal arts institution. Nearly any new venture that succeeds is one that is singularly obsessed with the meaning, mantra and tasks at hand. It is nearly impossible to serve two masters. Yet, due to budget constraints and needs, this is exactly how the CR&I was set up. Both the CR&I and IEP directors had 50% teaching roles. Essentially, they were building a new organization from scratch with only half-time available. From a management perspective this is akin to trying to run with only one leg, or at least using two legs but running half the time in different directions. The point is clear, and is offered to anyone attempting to start a new organization with such far-reaching implications. Ensure the key management person (or persons) is fully allocated to the task at hand. Any divergence of attention, no matter how well intended, only serves to take away from the priority at hand. Mixing and matching budgets to pay for a position is a common practice in higher education. Unfortunately, it violates three of the four primary practices in what really contributes to long-term business success. Maximize potential for success – focus.

A component or principle of experiential learning is reflecting on the experience. To create more innovative engineers capable of helping their organizations stay competitive in today’s blistering global marketplace, higher education must provide them the ability to fail. One student reflected that, “I think that having the freedom to develop an idea and also to fail is important. Allowing students to develop their own "project" … is a good way to grow and develop engineers.” The CR&I was one such attempt to use experiential scenarios with the distinct possibility of failure to train, innovate and add value at the same time. Take the experience of the CR&I and leverage it for success.

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