EMILE: A concerted tech-based entrepreneurship effort between Engineering and Business

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Abstract

Beginning in the fall of 1999 a team of faculty from engineering and from business at the University of Missouri-Columbia joined efforts to address the following question: How can we adapt and build upon the work of other universities to close some of the competency gaps for those students hired as engineers and managers engaged in manufacturing and innovation, given the existing needs and realities of our current and future manufacturing enterprises and the University of Missouri’s educational and industrial environment? In addition, the team considered a secondary question: How can the educational process instill a more entrepreneurial attitude in our undergraduate students?

The result of these efforts was the submission and approval of a proposal to the CCLI Program, Division of Undergraduate Education of NSF to adapt, test and adopt a strategy that puts together faculty, students, administrators and staff in implementing a certificate program jointly offered by the Colleges of Engineering and Business. This endeavor stimulates technology-based entrepreneurship by teaming faculty and students in an experiential learning environment and draws upon the Manufacturing Engineering Education Partnership -Learning Factory. The objectives are achieved through dynamically managing and implementing the following tasks: developing a sequence of three team taught (& designed) courses; the active use of an enhanced facility named Entrepreneurship-Manufacturing Innovation Lab Experience (EMILE); collaboration with industry partners; project assessment; and outreach to different stakeholders and interested parties.

The courses focus on the Enterprise: Conception, Design, and Operation. The teaching/learning strategy is based on team teaching between the engineering and business faculty with active and experiential learning, reducing or eliminating traditional lecturing. Interdisciplinary teams of students work together in generating ideas for product development, creating the business and operational plans of an enterprise that delivers a product or service to its customer base. Throughout the sequence, the teams are encouraged and required to use EMILE and other support facilities to insure that they integrate technology from conception to operation. EMILE’s main hub is a 3,143 square-foot high-bay mini-factory whose equipment and resources are being configured and enhanced for production and to induce active learning. To insure proper progress and continuous improvement the team-designed assessment plan spans program evaluation to stakeholders’ opinions, to class performance, and delivery by the faculty members.

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1. Introduction

The rapid pace of technological developments, particularly in the discovery, renewal or new applications in materials science, automation, the refocus to customer satisfaction (e.g. build-to-order and mass customization), and the exponential growth in IT/IS technology has, and will continue to have, a tremendous impact in ‘conceptualizing, innovating and effectively managing’ organizations.\textsuperscript{1-3} This has a tremendous impact on the human resource needs of manufacturing enterprises and certainly for the new engineers and managers who will become part of the workforce.

Since the 1980s we have seen several initiatives supported by the government, national laboratories, the private sector, and professional societies stimulating one or more of the following:

- integration of research and development in the undergraduate curriculum,
- more hands-on strategies towards learning/teaching engineering and technology,
- partnerships across disciplines to stimulate a more integrated educational process in science and engineering,
- strategies to incorporate the K-12 community into the learning/teaching/outreach activities related to Science, Math, Engineering and Technology (SMET).

Concurrently, we have seen innovation and manufacturing take a revived place in the spotlight after the difficulties and global competitive pressures of the 1980s.\textsuperscript{18-19}

As a result in the past 10 years we have had a host of initiatives and partnerships throughout academic institutions. In 1993 The Pennsylvania State University, the University of Puerto Rico-Mayagüez and the University of Washington initiated The Manufacturing Engineering Education Partnership: The Learning Factory (MEEP-LF). “LF is both a new kind of curriculum, and an integrated manufacturing facility. It integrates a practice-based curriculum that emphasizes manufacturing, design, and business realities, with physical facilities for product realization, in an industrial-like setting.”\textsuperscript{20-22} Lehigh University developed the Integrated Product Development (IPD) Program (1994), which emphasizes: “solid grasp of engineering science and business fundamentals, good communication skills, superior understanding of the design and manufacturing process and thorough appreciation of the value of teamwork.”\textsuperscript{33} Stanford University founded in 1996 the Center for Entrepreneurial Studies to build understanding of the issues faced by entrepreneurial companies and individuals. The Massachusetts Institute of Technology has the MIT Entrepreneurship Center “to train and develop leaders who will make high-tech ventures successful. To that end, we offer educational programs to inspire, train, and coach new generations of entrepreneurs from all parts of MIT.”

Although coming from different paths and environments, these successful endeavors are driven by some key fundamental objectives:

- stimulate innovation and entrepreneurship in education and research related to manufacturing enterprises,
- conduct interdisciplinary teaching/research activities at all levels,
- provide a real/hands-on learning/research environment,
- insure strong industrial participation,
- make available this scenario as early as possible in the careers of young, promising engineering, science, and business students.
In this manner these partnerships address young graduates’ competency gaps that have been identified by industry and professional societies. Nonetheless, ample opportunities and needs still exist to further expand and transport successful endeavors to other institutions and environments with the corresponding adjustments and enhancements. At the same time innovation is key to current and future challenges that any society or country faces if it is going to stay competitive. In that regard sectors of the US scientific and technological community have worked together to discuss challenges and opportunities that users and researchers may need to address.

Since higher education is one of the key instruments in our society that facilitates intellectual development, innovation and research, it is proper that we continuously strive to better address some of the societal, organizational and individual needs spelled out by experts. In the fall of 1999 a team of faculty at UM-Columbia decided to address the following question: How can we adapt and build upon the work of other universities to close some of the competency gaps for those students hired as engineers and managers engaged in manufacturing and innovation, given the existing needs and realities of our current and future manufacturing enterprises and the University of Missouri’s educational and industrial environment? In addition, the team considered a secondary question: How can the educational process instill a more entrepreneurial attitude in our undergraduate students? The sections that follow describe the design efforts, the initial steps, current status of the effort and possible paths of evolution to address these questions.

2. Synergy: Engineering and Business from the start

A longitudinal and cross sectional review of several academic endeavors to restructure technological-based education during the past 15 years will show that many of these changes have been initiated within an academic unit, e.g. department or college. Yet a review of what industrial leaders claim as desirable skills and attributes for young graduates requires a truly interdisciplinary design. This requires academicians to work differently in the design and development of academic initiatives to better influence the educational process and experiences of students. Furthermore the design of the efforts needs to consider expected results, learning styles, contents, appropriate methodology and continuous improvement.

In an effort to develop an experience that will address the two primary questions, while attempting to work differently in a traditional academic setting, an interdisciplinary team of faculty from the Colleges of Engineering and Business began working using as a reference template the efforts conducted by The Manufacturing Engineering Education Partnership (MEEP). Also the team adopted strategies and materials from other experiences to enrich the quality of the design and deliverables. The following major adjustments, and hopefully improvements, were incorporated from the beginning:

- team is integrated by business and engineering faculty and staff
- deliverables are targeted for students in both colleges working in teams
- focus is the enterprise as a system, as opposed to just the design of an innovative product
- courseware has been designed, and will be delivered, by interdisciplinary teams
- courseware is based on active-learning

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These adjustments were made because several of the competency gaps among graduates are correlated, and with the desire to address some basic ‘ingredients’ such as: having an integrated view of what is needed, stimulating the educational/research environment to incorporate this view vertically and horizontally, being more practice-based/hands-on, being innovative and flexible, and having continuous commitment from principal stakeholders. To achieve these adjustments explicit support was required, and obtained, from both Colleges, the University and external sources. The team began concurrent work in delineating project objectives, fine-tuning them and seeking internal and external support. Four major results were achieved:

- University commitment of four permanent faculty lines (two in each college) beginning in the fall 2001
- a two-year proposal approved by the National Science Foundation (NSF-DUE-CCLI Program) to support the development of the curriculum
- the College of Engineering and the University’s Research Division provided start-up funds to acquire equipment and materials
- collaboration has been obtained from industrial, academic and other internal partners.

The composition of the team makes possible synergy in our work and activities and facilitates the development of operational objectives that will better serve the student population and small and large enterprises. The vision is to graduate engineering-savvy business students and business-skilled engineering students.

3. Entrepreneurship, Innovation, Theory and Activity based Learning

It is common that our student population comes from backgrounds that promote very rigid and structured learning environments, in which students are prompted to take notes and be passive, learning and operational objectives are unclear to the students and the focus is on memorization, testing and an expectation of failure-free performance. However, much of this structure is at odds with some of the skills, abilities or behaviors expected in a heavily competitive environment. Graduates everywhere are expected to have initiative, “hit the ground running”, be aware of the internal and external environments, be life-long learners, be creative and think on their feet.

To attempt to harmonize all these expectations our team is focusing on blending entrepreneurship, stimulating innovation and creativity, using required theory and designing an activity-based learning environment. Thus our overarching themes are based on:

- team-developed courseware and activities, which implies continuous interactions of those responsible for developing the course with feedback and criticism from the whole team;
- team-taught courses, in which those responsible for teaching the course will be in the classroom throughout the semester and will jointly teach the class;
- interdisciplinary student team-work/learning, which requires interaction between students with different disciplinary backgrounds;
- emphasis on activity-based course delivery, with traditional lectures used as a last resort;
- integration of theory and application -focus on application of theoretical/text learning to structured application, e.g., the use of Legos®, and practical application, e.g., client such as nursing homes/day care facilities.

This emphasizes that we do not rely on the textbook as the syllabus or curriculum.
A sequence of three practice-based courses was conceptualized, and is under development and continuous fine-tuning. The focus of this sequence, as depicted in Figure 1, is the enterprise, from conception to operation. Concurrent course sections are available at each College. The coordinating responsibilities are by the Department of Industrial and Manufacturing Systems Engineering in the College of Engineering and the Department of Management in the College of Business.

![Figure 1. The three-course sequence](image_url)

As illustrated in Figure 1, these three courses include Engineering 3X1/Management 3X1, Engineering 3X2/Management 3X2, and Engineering 3X3/Management 3X3. Although the courses are concurrently coordinated, engineering students enroll in Engineering 3X1 and business students enroll in Management 3X1 – thus overcoming the student “fear factor” of enrolling in courses outside their own discipline. Both “3X1s”, however, will meet as one – in the same room, at the same time, with the same team of faculty throughout the semester.

**Enterprise Conception** focuses on developing a business and technology plan, which introduces and blends identification of a client need, product development, engineering, marketing, costing, and production using a business plan activity as the template for development of the conceived enterprise. **Emphasis is placed on creativity, innovation and entrepreneurship.** Many of the generated ideas in Enterprise Conception will be carried forward throughout the sequence in an effort to provide continuity, demonstrate an integrated process, promote the development of new business ventures and provide continuous enhancement to the designs. **Enterprise Design** builds upon the plan developed in Enterprise Conception and expands it to an operations plan, including such specifications as advertising designs, facility layout, selling and distribution channels, engineering product designs, accounting procedures, manufacturing process design, and product prototypes. **This course emphasizes design and innovation.** **Enterprise Operation** builds on the operations plan developed in Enterprise Design and expands into the manufacturing, sale, and distribution of products. The aim is that students in the course will perform the day-to-day operations of the enterprise that was conceived and designed in courses one and two with actual enterprise operations occurring in the Entrepreneurial Manufacturing Innovation Laboratory Experience (E-MILE) facility. Enterprise Operation emphasizes operations – financial, control, manufacturing, sales and delivery.

Initially a theme will be picked for Enterprise Conception. Students are assigned to interdisciplinary teams and work in developing a solution to a problem, designing a product that fits a real need. At the end of the semester the teams will deliver a preliminary business plan of the conceptualized enterprise and a prototype (or mock-up) of the product that this business will manufacture. The resulting plans will be the input for course 2, Enterprise Design, where student teams will “explode” details of the structure, processes and procedures of the company. Subsequently the results of these designs become input for course 3, Enterprise Operations. This concept adopts and adapts from MEEP, particularly from the approach taken at the University of Puerto Rico-Mayagüez, where in the Entrepreneurship course the students deliver preliminary business plans and prototypes and these become input to the course in Concurrent Engineering. 32
To pilot course 1, Enterprise Conception, students are being recruited as early as their sophomore year. However, a parallel strategy is under development to orient and recruit aggressively from freshmen students. The objective is to motivate students to enroll in course 1 in their sophomore year and to continue until completing the sequence. Every student who completes the sequence will receive a certificate signed by the Deans of Engineering and Business.

Table 1 depicts the ten skills agreed upon by the team to be developed throughout the course sequence. These skills are based on the needs identified by stakeholders, work done in similar endeavors and the interdisciplinary population of students. This skills set encompasses technical, analytical and people-oriented attributes and draws upon the fundamentals of theory and practice in business, communications and engineering. Since students come from different disciplines and backgrounds, it can be expected that participants will form a heterogeneous group in terms of the depth that they have in several of these skills.

Table 1. Skills to be developed throughout the course sequence

<table>
<thead>
<tr>
<th>Skills</th>
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<tbody>
<tr>
<td>1 Intellectual Curiosity</td>
</tr>
<tr>
<td>2 Empathetic Listening and Questioning</td>
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<tr>
<td>3 Networking</td>
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<tr>
<td>4 Analytical decomposition of complex processes/systems</td>
</tr>
<tr>
<td>5 Solution-oriented Thinking</td>
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<tr>
<td>6 Ability to move between historical, analytic thinking (cognitive representation) and future-oriented (learning by doing)</td>
</tr>
<tr>
<td>7 Willingness to Experiment</td>
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<tr>
<td>8 Capacity to accept Constructive Critique</td>
</tr>
<tr>
<td>9 Creative writing focused on narrative</td>
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<tr>
<td>10 Persuasive extemporaneous oral communication (“thinking on feet”)</td>
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</table>

These skills were used as the basis to develop the learning objectives of the courses. Table 2 shows the learning objectives developed for Enterprise Conception.

Table 2. Learning Objectives for Enterprise Conception

<table>
<thead>
<tr>
<th>Learning Objectives</th>
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<tbody>
<tr>
<td>1 Understand the characteristics of successful entrepreneurs</td>
</tr>
<tr>
<td>2 Understand sources of creativity and diffusion of innovation</td>
</tr>
<tr>
<td>3 Describe the sources of potential business opportunities</td>
</tr>
<tr>
<td>4 Describe the market assessment process</td>
</tr>
<tr>
<td>5 Conduct project management</td>
</tr>
<tr>
<td>6 Explain new venture strategy</td>
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<tr>
<td>7 Explain supply/value chain</td>
</tr>
<tr>
<td>8 Create a new venture business plan</td>
</tr>
<tr>
<td>9 Evaluate the quality of a business plan</td>
</tr>
<tr>
<td>10 Describe issues associated with intellectual property/patents</td>
</tr>
</tbody>
</table>
Evaluation instruments and activities have been designed to understand the skills that each student has and to induce a progressive development of the students’ skills. The focus of our approach is to develop and fine-tune learning objectives for each course so that the activities conducted in each one will comply with these objectives and will enhance the mastery that each student has over the skills. It is extremely important to recognize that activities, instruments, documents and the skill set and learning objectives are “living and evolutionary” actions to guarantee continuous improvement and attainment of the vision and overall objectives. Otherwise stakeholders are not well served.

Tables 3a and 3b show the timetable for piloting and institutionalizing the three-course sequence and the planned offering schedule.

<table>
<thead>
<tr>
<th>No.</th>
<th>Course</th>
<th>Pilot Run</th>
<th>Fine-tuning</th>
<th>Institutionalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Enterprise Conception (EC)</td>
<td>Spring 2002</td>
<td>Summer 2002</td>
<td>Fall 2002</td>
</tr>
<tr>
<td>2</td>
<td>Enterprise Design (ED)</td>
<td>Fall 2002</td>
<td>Spring 2003</td>
<td>Spring 2004</td>
</tr>
<tr>
<td>3</td>
<td>Enterprise Operation (EO)</td>
<td>Spring 2003</td>
<td>Summer 2003</td>
<td>Fall 2004</td>
</tr>
</tbody>
</table>

Table 3b. Planned offering schedule

<table>
<thead>
<tr>
<th>Semester</th>
<th>Spring 02</th>
<th>Fall 02</th>
<th>Spring 03</th>
<th>Fall 03</th>
<th>Spring 04</th>
<th>Fall 04</th>
<th>Spring 05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course</td>
<td>#1 (EC)</td>
<td>#1 (EC)</td>
<td>#2 (ED)</td>
<td>#3 (EO)</td>
<td>#1 (EC)</td>
<td>#2 (ED)</td>
<td>#3 (EO)</td>
</tr>
<tr>
<td>Offerings</td>
<td>#2 (ED)</td>
<td>#3 (EO)</td>
<td>#1 (EC)</td>
<td>#2 (ED)</td>
<td>#3 (EO)</td>
<td>#1 (EC)</td>
<td></td>
</tr>
</tbody>
</table>

This schedule will enable students to maintain continuity in the sequence and will allow them to begin the sequence in either fall or spring semesters.

4. EMILE

A critical component of this effort is the physical infrastructure that allows students, faculty and industrial representatives to collaborate in the overall process, from conception to operations. At MU this core component is EMILE, the Entrepreneurship-Manufacturing Innovation Lab Experience. EMILE is a facility similar to MEEP-Learning Factory, in which creativity, innovation, product design and development, business matters and teamwork are stimulated through physical proximity and communication linkages. The configuration includes shop facilities and computer resources for product-process design, and monitoring and control. Industry-supplied or in-house developed equipment will be devoted to production, and networking that permits the operation of a manufacturing system.

The idea behind E-MILE is replication of the realities of a manufacturing enterprise in an academic atmosphere. The primary goals for E-MILE are to:

- Be a main facility that will host an array of processes and technology suited to promote innovation, design and manufacturing and be able to share expertise with industrial partners or other facilities as needed
- Be able to network, via electronic communication, with other organizations
- Stimulate new ideas/ventures that may become spin-offs of enterprises or more advanced research projects in product design and manufacturing
The core of E-MILE is a high bay area of 3,143 square feet. It has a layout, as shown in Figure 2 of six sections:

- Computer Aided Design (CAD) and metrology,
- Numerical Control (NC) for NC milling and turning,
- a DEC MH Cell for programmable logic controlled material handling,
- a Technovate CIM Cell for programmable control and computer integrated manufacturing,
- Conventional Machine for conventional milling and turning
- a Supply and Reference Room for storage of manual and small parts inventory.

Certainly the use of EMILE is complemented by other supporting facilities at MU that are relevant in the product-process-manufacturing continuum, including Machine Shop, Computer Laboratories, Modular Lab for Systems Integration and Control, and Human Factors laboratory.

The capacity of this core EMILE facility will be augmented to avoid bottlenecks and provide new capabilities. That expansion, coupled with other facilities, will be used to promote product design, prototyping and actual production. This integrated framework will stimulate a manufacturing-entrepreneurship "culture" that will increase the institutional capability to create, innovate, investigate and execute with explicit considerations of business aspects.

5. Industrial Partners

Industrial participation and support is important to the long-term success of this effort. The stimulus for a more practice-based and entrepreneurial educational process must be rooted in the business sector. This collaboration promotes a clearer learning process of what innovation means to any enterprise, including products/processes conceptualizations and concurrently provides an invaluable array of experiences to students and faculty. Business partners have the opportunity of positively influencing the educational process of students. Furthermore, these industrial partners will have access to a pool of talented students with a more comprehensive set of experiences in manufacturing and business aspects, while newly graduated students will find better employment or advanced scholarly opportunities.

Currently we have six major partners: 3M, Anheuser-Busch, Americare, Hallmark, Nordyne and MU’s School of Nursing. The faculty team has made presentations to Industrial Advisory Boards in Engineering and Business and continues to strengthen links with entrepreneurs and enterprises. The partners form an Advisory Board to EMILE in a continuous effort to work closely with entrepreneurs, small and large enterprises to identify long-range initiatives that may
be suitable for pilot projects in E-MILE. Graduating seniors will be a strong link to new and existing enterprises in the future as they enter the workforce and identify and lead new activities.

6. Evaluation: Multiple Components

To institutionalize and continuously improve it is necessary to understand participants’ outcomes, satisfaction, and opportunities for improvement. Therefore a critical task is to design and implement an assessment process that will provide feedback from the main stakeholders: students, industry, and faculty. The components of this strategy will be to conduct internal and external assessments, using multiple-criteria to measure quantitative and qualitative areas of interest. We are putting in place an assessment plan that is both summative (assesses the effectiveness of the approach) and formative (provides feedback to help improve the approach). Since this effort represents a new venture at MU the team is working to assess the design and the overall project.\textsuperscript{11, 14, 26}

To achieve our goal of using evaluation for both summative and formative purposes, we are implementing an evaluation approach based on the Discrepancy Evaluation Model (DEM) to compare program performance with expected or designed program outcomes.\textsuperscript{15} A DEM design realizes our goal of assessing the worth of a project while simultaneously gathering information to improve the project. The effort is aligned with proponents of Total Quality Management and Continuous Improvement and the proper design and evaluation of an endeavor when the primary responsibility for the evaluation falls on “insiders” of the endeavor.\textsuperscript{15, 25, 27, 28}

The assessment strategy, including the development of instruments, draws from previous assessment work done in MEEP and adopts and adapts MEEP’s performance indicators.\textsuperscript{23} Data gathering is aligned via straightforward questionnaires insuring both formative and summative assessment. Based upon suggested methodologies full-participant questionnaires will be administered to two groups: those enrolled in all three-courses in the sequence and those not enrolled in all three.\textsuperscript{31} In addition to the DEM methodology, a slightly modified questionnaire will be sent to students one, three, and five years after graduation. This final summative evaluation will compare participating graduates with those students who did not participate in the proposed approach. This effort is in agreement with modern accreditation criteria such as ABET 2000 and the AACSB (Association to Advance Collegiate Schools of Business) International.

7. Outreach

EMILE’s effort is directed toward influencing how students think and learn about technically-based entrepreneurship. The intention is that these changes and potential opportunities reach many students early in their educational career and expand the pipeline of engineering students, bringing as much external collaboration as possible. Therefore utilizing ongoing initiatives with (and in) the local community, we will reach the K-12 classes to illustrate for them and mentor them in the importance of technology-based entrepreneurship and the potential for business developments. A research graduate assistant is dedicated to the design and implementation of a web site (http://www.missouri.edu/~emile/) to reach current and potential stakeholders, namely: students, K-12 community, business people and enterprises. This site will be under continuous evolution during the next two years to ensure that its design conforms to the needs of these stakeholders and that the pages directed towards K-12 are as effective and appealing as possible.
The mid- to long-term objective is that the K-12 community can experience a “virtual environment where manufacturing-entrepreneurship comes to school.”

Concurrently the project team is revising its ongoing marketing strategy to recruit students from the existing MU population. Although initially it is expected that most students enrolled in the course sequence will be in engineering and business, the overall strategy is directed towards all students on campus who may have an interest in the intersection of entrepreneurship-innovation-technology-business.

8. Next Steps

As with any new initiative EMILE requires continuous monitoring to assure the progress and systematic closure of project tasks, the accomplishments of its initial objectives, its institutionalization and the “completion of the innovation-entrepreneurial loop”. The project team meets every two weeks to review the status of project tasks, fine-tune previous agreements and work on the development and details of primary tasks that relate to curricular, infrastructure, partnering, outreach and assessment objectives. Also the team emphasizes the importance of open and continuous communications with academic administrators, sponsors and the advisory board to guarantee their participation and support. Finally, it is important to keep in mind that one of the expected spin-offs of our endeavor is ideas for new ventures (enterprises), which will require further coordination and support. To address this very important need the team is interacting with MU’s Research Division and specifically its Office of Technology and Special Projects. This office facilitates guidance regarding technology transfer, patents, licensing and relevant aspects related to innovation and research. This aspect is critical to complete the innovation-entrepreneurial loop.

9. Summary

EMILE is a new and innovative initiative at the University of Missouri-Columbia. It is the product of concerted teamwork between the Colleges of Engineering and Business to stimulate, promote and develop the education of technology-based entrepreneurship and the development of innovative need-based ideas in an academic setting. One of the expected outcomes is expanding the thinking and views of talented young individuals in the hope that they will influence the creation of new wealth. Another expected outcome is motivating students, academicians and business people to induce more creativity and innovation through real interdisciplinary team-based learning and teaching, placing emphasis on activity-based teaching and learning, and real life application focusing on the enterprise, from conception to operation. Central to this effort is the enhancement and use of physical facilities that promote the interaction of stakeholders to conceptualize, design, prototype and manufacture products driven by a market need.

10. References


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