Project Summary

The Enterprise Program--Interdisciplinary Product Realization

The proposed work seeks to design and bring into reality a new type of curriculum and interdisciplinary community whose members create new businesses, new products and who serve the needs of existing companies. To reach our objectives, we will adapt the Michigan Technological University's Enterprise Program, a revolutionary approach to undergraduate engineering education. If the proposed work is funded, we will create three main outcomes:

1. **Businesses**. We will have in place three Enterprises (a company run by students) that involve more than 110 business and engineering students and faculty.
2. **Curriculum**. An Enterprise curriculum (EC) will be in place. The EC will use the Internet to deliver four one-credit courses. These courses will facilitate learning of professional skills that are important to each engineering and business discipline. Concurrently, the EC will help engineers learn effective business practices and help business professionals learn the way of the engineer.
3. **Measurement System**. We will develop a pilot of an embedded formative assessment and evaluation system that facilitates and measures learning in the enterprises and other project-based courses and activities.

The Enterprise Program engages students with real-world challenges and fosters learning because realistic problems are supplied by industry partners. Instead of a classroom model, the program organizes students into Enterprises, each with about 40 undergraduate students (sophomore through senior) and a faculty advisor. The compelling aspect of the Enterprise Program is that there is substantial evidence of effectiveness in learning and the program is bringing in substantial financial resources.

Intellectual Merit. The proposed work will advance knowledge in the areas of (a) eliminating barriers in higher education and (b) in creating learning environments that are aligned with the needs of modern companies. Our team has significant past experiences (15+ years) in designing learning environments and in managing student projects. We are adapting a very strong model, and we have established purposeful collaboration with the leaders at Michigan Tech. While we have highly ambitious outcomes, we believe that a strong interdisciplinary team approach will allow us to reach our goals.

Broader Impacts. Modern companies need graduates who can perform in cross-functional teams. An educational system that creates this outcome will provide strong impact. This impact can then be magnified because this educational system can be transferred to other contexts. We are basing this educational system on trust and respect for others, regardless of background, gender and ethnicity. Also, we are breaking down artificial barriers between departments and colleges. We believe that major impact is attainable. To quote Margaret Mead, "*Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it is the only thing that ever has.*"

Narrative: The Enterprise Program--Interdisciplinary Product Realization

1. PROBLEM DEFINITION

At the University of Idaho, we have a tradition of excellence in engineering and business education. Exemplary programs include the Integrated Business Curriculum (IBC) in the College of Business and Economics and the Idaho Engineering Works (IEWorks) in Mechanical Engineering Department. Because of these endeavors, we have a community of faculty members with rich experiences, and knowledge of pedagogy. In the past several years, this community has been blessed with three National Science Foundation grants. In the proposed work, we will align our existing strengths to create an interdisciplinary learning environment that unites business and engineering learners and teachers.

There are compelling needs for the proposed work. One reason involves fundamental issues with learning--many new products fail in the market place, and we hypothesize that this failure is due in part to a lack of collaboration between business and engineering professionals. This lack of collaboration is a natural result of an educational system that segregates learners into isolated curriculums. This same problem arises in academia---at our university, there is little collaboration between departments and colleges. The second need arises because societal and economic factors are pushing engineering educators to do more with less. Indeed, this push provides an opportunity--overloaded faculty members are opening up to the idea of change ("*we need to do something!"*). Similarly, the Internet provides an opportunity to innovate with technology while reducing the associated cost of delivering courses. In summary, cross-functional teaming by business and engineering educators provides a marvelous opportunity to reduce the cost of education while dramatically enriching the learning of our young people.

Due to cultural and institutional issues, cross-functional teaming at the university level is difficult. However, we have found a model (our adaptation source) that appears very promising for our context: Michigan Technological University's Enterprise Program. If the proposed work is funded, we will adapt the MTU model and create three main outcomes:

1.) **Enterprises**. We will set up three enterprises, each with an engineering and business advisor. Each enterprise operates as a company, involves 20-40 students, and takes on and accomplishes projects sponsored by companies, entrepreneurs or investors.

2.) **Enterprise Curriculum** (EC) We will set up a path to graduation that works across boundaries. A student can join the Enterprise Program and graduate with a traditional degree (e.g. M.E., E.E. Business). The EC will be comprised of four courses, each one credit, that span a four-year curriculum. These courses will facilitate learning that is important in all curriculums (e.g. teamwork, ethics, modern company practices, assessment, reflective practice, etc.). This learning will be delivered in a way that develops engineers who think like business professionals and business professionals who think like engineers.

3.) Measurement System. We will pilot test a portfolio system as a means to facilitate, assess and evaluate learning.

2. LITERATURE REVIEW

Some businesses are outstanding (world class) based on both the employee perspective (this is a great place to work!) and the bottom line results. One such company, IDEO (Kelley, 2001; see also www.ideo.com), has been featured on network television (ABC News, Nightline). This video presentation presents a compelling example of a high performance company. In a six year study, Collins and Porras (2002) examined 18 exceptional companies and asked *what are the factors that make truly exceptional companies different from other companies*? Relevant themes that emerge include (a) a focus on timeless human values, (b) an ability to embrace contradictory extremes (you can make profit AND make a genuine contribution to the world), (c) goals that are so ambitious that they are almost ridiculous, (d) cultures that are nearly like a cult, and (e) a prototyping mindset—take action until you figure out what works.

Buckingham and Coffman (1999) studied managers who excel in bringing out exemplary performance in those who are managed. They report that great managers focus on treating people as unique individuals. Great managers recognize that they cannot change people, and so they identify innate talent, and create an environment in which innate talent can flourish and grow. Their research revealed that the strength of a workplace within a company can be measured with a set of 12 questions. These questions can be used to design a strong workplace environment.

There are many references that describe effective product development. Ulrich and Eppinger (2000) define a product as *something that is sold by an enterprise to its customers* and they state that economic success of a manufacturing firm "*depends on their ability to identify the needs of customers, and to quickly create products that can meet these needs and can be produced at a low cost*." They identify three related functions that are central to product development: marketing, design (both engineering and industrial) and manufacturing. Ulrich and Eppinger emphasize that companies must define their process (sequence of actions) for developing products and their organizational structure. However, developing great products is difficult and often not attained. Ulrich and Eppinger (2000) state that the beginning phases of product development (the front end) require tremendous interdisciplinary collaboration. Cagan and Vogel (2002) introduce the concept of a "breakthrough product," a winning result that integrates societal, economic and technological factors. Key to breakthrough products is masterful performance during the beginning phases ("*fuzzy front end"*) of a project and using an interdisciplinary team.

Regarding teaching and learning, Bransford et al. (2000) state that *"a new theory of learning is coming into focus that leads to very different approaches to the design of curriculum, teaching and assessment."* They state that evidence from many different branches of science is converging to provide a much richer understanding of how to structure learning. The authors relate learning theory to educational practice and suggest that a good learning environment should be learner-centered, community- centered, assessment-centered and knowledge-centered.

An educator who is learner-centered should understand recent developments in cognitive neuroscience. Hudspeth and Pribram (1990) have found that the frontal cortex, which is responsible for higher cognitive function, is not fully developed until age 22 or beyond. Thus, the thinking skills that are essential to engineering are late developing. Many other authors have reported important findings relevant to understanding the higher level thinking skills associated with the frontal cortex (e.g. Churchland and Sejnowski, 1988; Gazzanaga ,1989; Geschwind and Galaburda, 1987). These findings provide a physiological basis for understanding why it is hard to teach for performance--the cognitive skills of many students are not yet fully functional and so their abilities for high-level learning need to be developed. That is, the process of learning is a correlates with measurable changes in the physical structure of the brain. Thus, the learning environment should be enriched in order to accelerate brain development.

An educator who is learner-centered should understand the process of human development (Hunt, 1971; Duncan-Hewitt et al., 2001) As learners grow in their cognitive abilities, they move through distinct stages. Movement through stages requires specific types of experiences and even when these experiences are present, movement takes significant time and immersion. Effective educators design learning environments that cause movement through stages of development.

Many authors have described effective learning environments using the concept of community. Boyer (1995) described the Basic School, his vision of what excellent education should look like at the K5 level. The basic school is a **community for learning**, a place where everyone comes together to promote learning. Each classroom is itself a micro-community, yet all are connected by a shared sense of purpose. The 1998 Boyer Commission states "*We believe that the state of undergraduate education at research universities is in such a crisis, an issue of such magnitude and volatility that universities must galvanize themselves to respond."* The report claims that our research universities produce students who lack a coherent body of knowledge and a sense of continuity between courses and disciplines. The idea of community is central in Boyer's life work and in the findings of the most recent Boyer commission.

Creating change in higher education practice is very difficult. DuFour and Eaker (1998) and Eaker et al. (2002) discuss the process of change as applied to K12 educators. They believe that the most promising strategy for substantive improvement is developing the capacity of teachers to function as a professional learning community. Relevant characteristics of a professional learning community include (a) timeline core values, (b) collective inquiry, (c) collaborative teams as the unit of practice, (d) action orientation and experiment, (e) continual focus on getting better, and (f) a results orientation.

Regarding assessment practice, modern references include Pellegrino et al. (2001), Black and Wiliam (1988), Angelo and Cross (1993) and Stiggins (2000). The central idea is to shift from an emphasis on teaching to an emphasis on learning. The process of assessment is used as a central strategy to promote learning.

Regarding curriculum and course design, there are many references (e.g. Erickson, 1998; Wiggins and McTighe, 1998; Beyerlein et al., 2003). Seminal work has been done Wiske (1997) and Blythe et al. (1998) who developed an overarching framework called the *Teaching for Understanding Framework*. These researchers believe that understanding is the ability to carry out performances that simultaneously demonstrate and advance competence. These performances are relevant to and typical of performances carried out by professionals in the discipline. The *Teaching for Understanding Framework* is a systematic method of curriculum design so that learners can, at the end of the units, demonstrate their understanding by their ability to carry out complex, discipline-specific performances.

Over the last decade, an inter-disciplinary community of educational practioners has organized around a concept they call "Process Education." This community of practioners has emerged with an emphasis on growing broad, transferable learning skills for a changing economy (Beyerlein, 2003). Implementation of this philosophy involves using innovative processes and tools to create learning environments that are engaging, challenging, and efficient in improving students' learning and self-assessment skills within a discipline (Hanson and Wolfskill, 2000). Process education is characterized by balanced attention to skill development and disciplinary competence with frequent use of mentoring and assessment as a vehicle for elevating performance (Krumsieg and Baehr, 2000).

To summarize this literature review, we believe that the literature is suggesting three emerging trends:

1.) There is a new way to organize and manage companies that is exemplified by firms such as IDEO.

2.) Educators should purposefully structure knowledge, experiences, the environment, and community in order to facilitate learning and growth in human potential.

3.) The way to create transformation change in educational practice is to develop the ability to work in professional learning communities.

Our hypothesis, to be explored in this project as well as in the future, is that the high-performance company, the change process for faculty members, and the enriched learning environment are very similar entities.

3. PREVIOUS WORK AT THE UNIVERSITY OF IDAHO

To assess the viability of creating enterprises, we surveyed ongoing activities. For two years, Professors Elger and L. Morris have collaborated on interdisciplinary projects in the context of a junior level engineering course. This collaboration has resulted in two projects that have been funded by the National Collegiate Inventors and Innovators Alliance. Another strength involves funded projects in the ME Capstone course. This year, there are five projects that could be developed into enterprises. Two projects are funded at the $10,000 level, two are funded at the $50,000 level and one project is funded at the $80,000 level. These projects involve six faculty advisors. In addition, there are many other relevant projects in both engineering and business. Thus, there are many opportunities to create enterprises.

Idaho has a tradition of compelling student projects because many faculty members are dedicated to student learning. In the College of Business and Economics, about 40 faculty members have collaborated to develop an enriched learning environment called the Integrated Business Curriculum (IBC). The IBC program was introduced in the fall of 1994 for reasons similar to those driving change in engineering education. Constituents were suggesting that graduates need a broader, multi-disciplined view of the business enterprise. In addition, the constituents wanted graduates with effective team and communication skills. The IBC program replaces the content from seven business courses with a series of six course modules delivered over two semesters. Student cohorts complete the 17-credit program in their junior year. The IBC program is team taught by a cross-disciplinary faculty team. An integral part of the year-long IBC program is faculty mentoring of student teams in comprehensive business projects and professional presentations. To provide context for learning and for business decision projects, the program uses "partner" companies such as Boeing Corporation, Hewlett-Packard, Harley Davidson, Starbucks, Coldwater Creek and Columbia Sportswear.

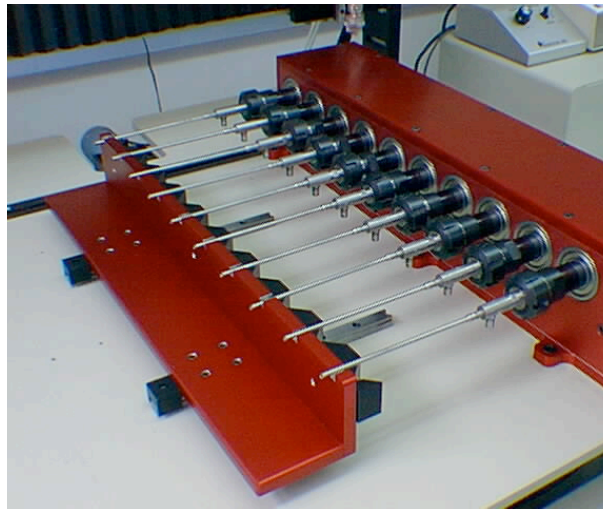

Fig. 1 Example of a capstone design project

In Mechanical Engineering, the faculty have developed an across-the-curriculum design sequence. The freshmen through junior years each involve a 3-credit design course. Notable features of this design sequence include: assessment, reflective thinking and journaling, use of peer-mentors in each class, many projects, and purposeful efforts to build community.

The ME design sequence culminates with a year-long capstone course that involves the Idaho Engineering Works (IEWorks) (Odom et al., 1999), a learning community of students and faculty. IEWorks, founded in 1994, is patterned after the legendary Skunk Works Project (the Skunk Works is described as *"a concentration of a few good people solving problems far in advance—and at a fraction of the cost—by applying the simplest, most straightforward methods possible to develop and produce new products*). IEWorks stresses human dynamics, communication, teamwork, personal reflection and professionalism. Much of the learning is related to surroundings and to social processes. To foster social and tacit learning, IEWorks is organized so that all senior design teams assemble their projects in a large studio. This studio is connected to meeting rooms, a fully-equipped machine shop, a computer lab, and an open-architecture office for mentors. This collection of facilities, known as the senior design suite, is special. When one walks into the suite, there is the look and feel of great engineering. Fig. 1 shows one example of a capstone project; other results are available online (http://seniordesign.engr.uidaho.edu/).

Fig. 2 shows one outcome of a recent project (NSF DUE #9952308, $92,289, April 2000 to March 2002). In this photo, an undergraduate mentor is teaching high school students how to use our new wind tunnel. This wind tunnel was designed so that beginning engineering students can acquire the skills for hands-on use in about ten minutes. The high school students pictured are participating in a very difficult engineering contest. This challenge provides a context to teach them concepts, math modeling, and the engineering process. Our philosophy is to put the engineering into the students' hands and align this with a rich immersion into content. Outcomes of the NSF project include creation of learning projects, construction of a wind tunnel, one MS thesis, 15 classroom implementations, a teaching workshop, and two refereed papers (Elger et al., 2000; Duncan-Hewitt et al., 2001a).

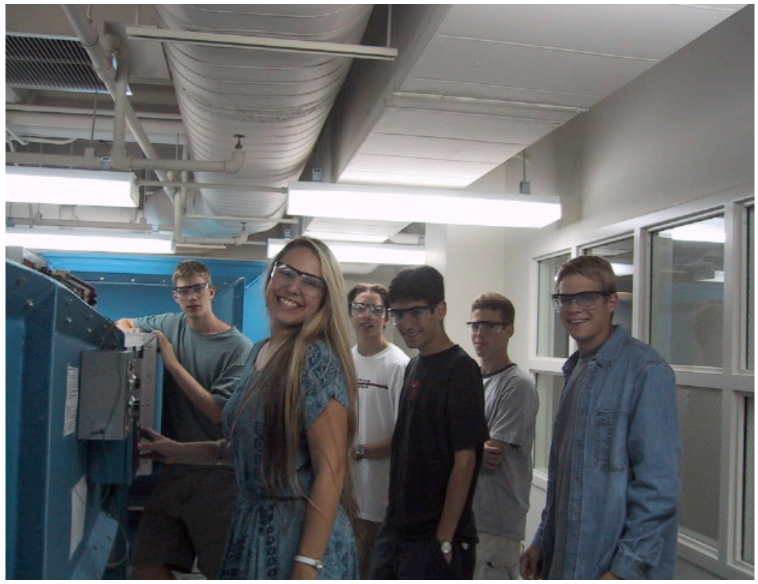

Fig. 2 Mentoring pre-engineering students

Fig. 3 shows an outcome of a second project (NSF DUE #0088591, $199,926, May 2001 to April 2004). The photo shows a protoype of a heated ski-glove. In Fig. 3 the black fabric on the glove is an emerging technology call Gorix. This fabric is an electroconductive fabric in which the electrical paths are woven into the fabric. The properties of Gorix allow the design of "smart fabrics" that automatically regulate temperature. In performing this four-week project, students integrated many elements of the engineering process such as math modeling, user survey, information collection, decision-making, goal formulation, idea generation, prototyping, and public presentation.

This second NSF project focuses on developing an across-the-curriculum program so that students will develop the skills needed to solve complex, open-ended engineering problems (we label this whole set of skills as the engineering process). This effort is founded primarily on the work of Charles Wales and Don Woods. Outcomes of the second project (in progress) include two papers, a book on problem solving, an on-line guide to effective teaching of problem solving, and an embedded assessment and evaluation tool (i.e. a portfolio system.) During the second NSF project, we encountered a challenging problem—how can we effectively drive change in academia? That is, how do we successfully get faculty members to change their practices to align with the

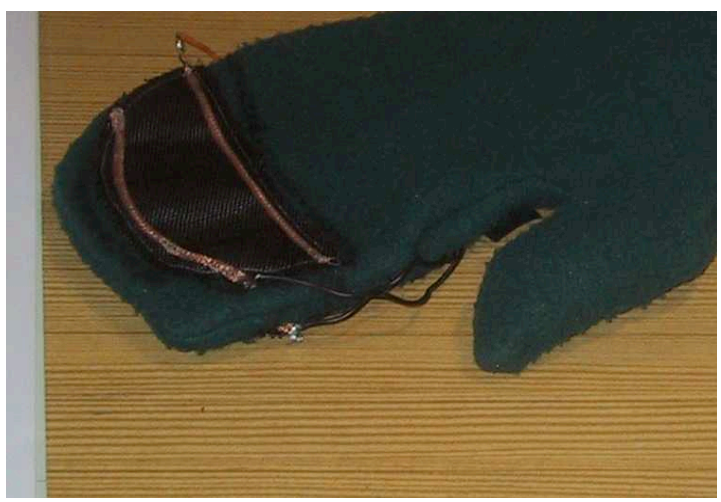

Fig. 3 Example of a prototype heated ski glove

sciences of how people learn?

Our third and most recent NSF-sponsored project: (NSF EEC-0212293, $375,000, August 2002 to August 2005) is focused on creating change on a broad scale in engineering education. Our approach to creating change is to create communities. Outcomes to date include creation of an interdisciplinary community (approximately 20) of faculty members, implementation of a peer-mentoring system in four courses, and creation of an experimental learning space called the MindWorks. In addition, we have completed approximately six conference papers.

To summarize, we have extensive previous work that forms the foundation for the proposed project. This proposed work is the logical next step—we want to combine efforts, thereby increasing efficiencies and enriching learning by creating an interdisciplinary learning environment.

4. WORK PLAN

4.1 Creating Enterprises

To create enterprises, we will follow the Mich. Tech. (MTU) Enterprise model--see letter of support from Dr. Sheryl Sorby. To strengthen the adaptation, we plan to visit to the Michigan Tech campus to gather information about their program.

In the MTU model, Fig. 4, each enterprise is designed to operate like a real company in the private sector. Each enterprise has a specific mission and expertise, such as wireless technology or hybrid vehicle design, that results in engineered products. Each enterprise stays in business (or goes out of business) by finding a market need and meeting this need in a way that generates income. People involved with an enterprise are inspired by the real-world possibilities of making a profit and creating intellectual property.

The overall environment of each enterprise is high-performance. We will model enterprises on the world class companies such as IDEO (Kelley, 2001). Each enterprise employee (students) will have a clear role and performance expectation that is aligned with their level of maturity, innate talents, and technical education. Students in enterprises will be expected to perform as professionals—quality engineering analyses, in-depth market analyses, effective experiment designs, etc. We will expect students to apply knowledge from the traditional engineering and business courses with rigor. In addition, students will be expected manage budgets and schedules, provide effective feedback

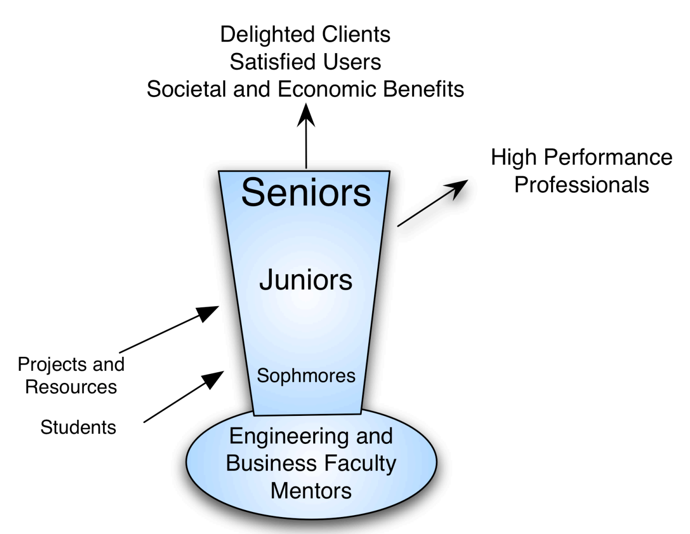

Fig. 4 Model of an enterprise

to peers and to continually exemplify excellence in all types of technical communication. A key feature of each enterprise will be regularly scheduled assessment of performance by one's peers.

An enterprise provides a structure for organizing students. Each enterprise will involve students from varied engineering and business disciplines. When appropriate, students from other disciplines such as architecture, sociology, etc. can join the enterprise program. Each enterprise will consist of 20 to 40 students. Sophomore students can join an enterprise for 1-credit internship per semester, and their role will be that of apprentice. Junior students (either new or students who have completed the sophomore program) will join an enterprise for 2 to 3 credits per semester. Junior students will be technical specialists in training—their role will be to assist with the detailed technical work. Senior students will be enterprise veterans—their role is to manage projects, develop new product ideas, solicit new funds, and to ensure that quality results are delivered. Based on Michigan Tech's experience, we anticipate no problems in recruiting students.

Each enterprise will have a primary advisor and a secondary advisor; one each from the colleges of engineering and business. The role of the faculty advisor is mentoring and coaching—we want the students running the enterprises. To find faculty advisors, we will advertise, and offer funding to start an enterprise. Since, there are quite a few faculty members already advising large student groups, we anticipate that we will have more than enough adviors who step forward.

Each enterprise stays in business by finding projects with industrial sponsors. AT MTU, the nominal cost of a project is $40,000, and $35,000 of this goes to the enterprise. The remaining $5,000 is used to support a staff person who finds projects and coordinates funding. Each enterprise can be working on muliple projects at any given time. Project funding is used to pay for the project and to incentivize team members. This model has been effective—at MTU the enterprises have delivered the promised results (as specified in the initial contract) to companies 100% of the time.

One concern with the enterprise program in long-term sustainability. Dr. Sorby (MTU) has recommended that we acquire the services of a half-time development person to interface with industrial sponsors. We have discussed this issue with our administrative leaders (see letters of support) and they are collaborating with us to find a solution.

To help launch the enterprise program at Idaho, we will set up a product development contest for students in their sophomore year. Students who enter the contest will work on interdisciplinary teams. They will develop an idea for a new project, they will build a simple prototype and they will complete a preliminary business plan. Projects will be judged and the winning team will be awarded $500. We will use the contest to build awareness and to recruit sophomores into enterprises.

4.2 The Enterprise Curriculum (EC)

The enterprise curriculum (EC) will be adapted from Michigan Tech. Following their approach, we will create one-credit courses that support enterprises. These courses will be designed to create learning of content and process knowledge in topics that are of general importance to professionals. These course topics will include teamwork, ethics, self-directed learning, communication, problem solving, peer-assessment practice, and project management, etc. In addition, we will design these courses so that business students learn engineering and engineering students learn business. In other words these courses will be special in two major ways: (1) they will create a type of interdisciplinary learning that is not typically attained in a traditional course, and (2) they will create efficiencies so various departments can avoid duplicating efforts.

Fig.5 illustrates the enterprise curriculum that we will create. There are four courses, labeled EC1 to EC4, each one credit. The courses build knowledge sequentially, they are organized around the common theme of working in a high performance company, and they are purposefully designed to support enterprises. The content of each course will be selected based on the perspectives of professors. Our initial thoughts for the courses are as follows:

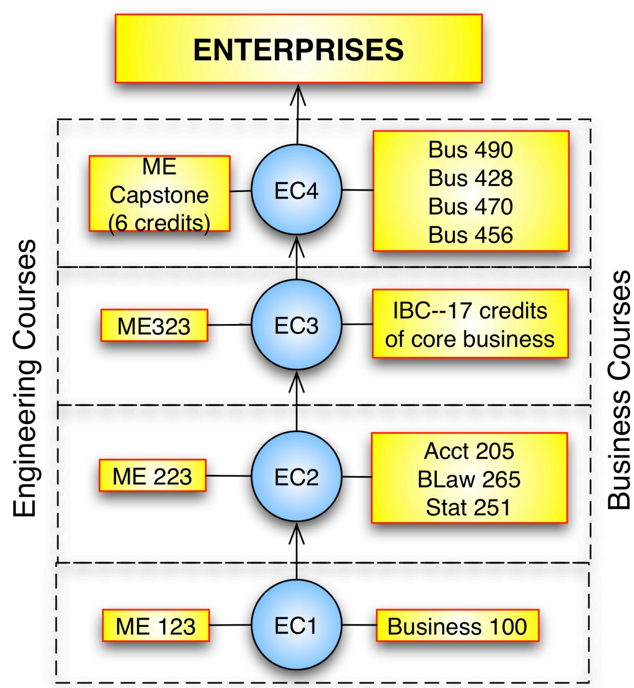

Figure 5 The enterprise curriculum

Careers in the High-Performance Company. (Freshman Course, 1 credit, EC1): This course presents a broad overview of the careers available in the modern company. It describes the various roles played by business and engineering professionals and how competent professionals interact in cross-functional teams. This course will help the engineering student learn business practice and the business student learn the engineering way.

Interdisciplinary Teamwork in the High-Performance Company. (Sophomore Course, 1 credit, EC2): This course presents an overarching model of the team as it exists in an outstanding company. This model, adapted from LaFasto and Larson (2001), focuses on five areas: (a) how individuals perform (b) how teams develop collaboration, (c) how teams solve problems, (d) how teams are led, and (e) how the organization interacts with the team via their systems of reward and resource allocation. Content of this course will include topics such as the stages of team development, steps in team formation, growing team performance through assessment, feedback, effective meetings, project planning, and creating a professional growth plan. Contextual examples in this course will be used to help all students understand the ways that engineers proceed and the ways that business professionals proceed.

Interdisciplinary Product Development in the High-Performance Company. (Junior Course, 1 credit, EC3): This course presents an overarching model of integrative product design and planning processes that occurs among professionals in design, engineering, marketing, finance, and operations management. This course will introduce the House of Quality, and help both business and engineering student learn how to interact in effective ways.

Managing Product Development in the High-Performance Company. (Senior Course, 1 credit, EC4): This course presents an overarching model of business and technical leadership and entrepreneurship. The course is tailored to grow students into leadership roles so that they can effectively manage enterprise teams and projects.

As shown in Fig. 5, the enterprise curriculum will be designed to grow high-level performers who can lead enterprises. Students who complete the enterprise curriculum and enter an enterprise will be recognized using a certificate program. In addition, we plan to align the enterprise program with existing minors in both business and engineering.

The enterprise curriculum will be designed to support traditional courses. Our idea is to improve collaboration with traditional educators by building the links that are shown in Fig. 5. The enterprise curriculum will be used in the traditional courses shown in Fig. 5—engineering courses on the left side and business courses on the right side. The idea is simple—for example, we will design EC1 so that the teacher of ME123 can use all or part of EC1 for her course. She will want to do this because it will reduce her work load while improving quality. In the same way, we will design each enterprise course to meet the needs of the faculty who teach appropriate courses. The traditional engineering and business courses shown in Fig. 5 represent connections we have established via personal communication with the instructors. During the course of the project, we plan to build additional connections.

Overall the intent of the enterprise curriculum is to grow community and build collaboration. The EC makes use of exemplary programs already established by the Colleges of Engineering and Business and brings together a community of faculty who focus on what their students learn.

4.3 Design and Development of the Enterprise Curriculum

To provide a cost-effective and sustainable approach, each EC course (Fig. 5) will be designed and delivered on-line. This on-line delivery provides a way to build interdisciplinary community because engineering students taking EC3 can interact in the on-line environment with business students.

To design and develop on-line courses, we will build upon past success. Our task leader is co-investigator J. Morris, who has previously developed a one-credit, on-line course for business students (www.uidaho.edu/cbe/bus100). In fact, we will modify Business 100 to created EC1. Our team will be assisted by the services of a local center called the Center for Teaching Innovation—see the letter of support from David Schlater.

One problem is how to get busy professors aligned with the enterprise program. To overcome this barrier, we will bring these professors into the front-end of the design process and identify their needs and interests. This includes meeting with both Idaho and Michigan Tech. Professors. To further build ownership, we will divide each course into parts and hire professors to develop each part. Dr. Morris used this model to create Business 100, and we are confident that this approach will work.

Following the spirit of enterprise, we will design the courses as a product that provides benefits to others. That is, we will find the needs, design a product that meets these needs, develop a marketing approach, and create a system to generate revenue. While creation of a commercial product is a long-term endeavor, the work described in this proposal will lay the foundation.

One key strategy to promote learning is application of Calibrated Peer Review (CPR), a software tool that facilitates writing as a mode of critical thinking. CPR was developed by a chemistry professor under NSF sponsorship. A student using CPR interacts with content knowledge and then writes a short essay in response to an assigned task. During this task, the student encounters guiding questions to foster critical thinking and to help the student organize their essay. After submission of their work, students read and assign a score to three "calibration" essays. When students demonstrate that they are competent reviewers, they read and assign a score to three anonymous peer essays, and finally, to their own essay. Regular use of CPR assignments teaches students to articulate ideas coherently and to critically assess both their peers' work and their own work. The beauty of CPR is its simplicity—assignments can be quickly designed, and once an assignment has been created, the work for executing this assignment is done by the computer!

4.4 Development of a System to Measure Learning

To measure learning in the enterprises (both courses and projects), we are going to design and create an embedded measurement system. The design objectives are:

a.) **Clear targets and regular feedback.** Students and professors will both have the same understanding of what strong performance looks like. Student will continually receive descriptive feedback that helps them improve their performances.

b.) **Appealing to users.** Students and professors will find the system appealing and relevant to learning and not burdensome.

c.) **Valid and Reliable data**. The system will produce multiple data sets so that validity and reliability can be established.

The basic methods we will employ revolve around the use of a professional portfolio that is maintained by students. As students progress through the enterprise program, they continually add evidence of their performance to this portfolio. This process will be scaffolded and structured so that we create learning outcomes in the process of building the portfolio. The basic design of the portfolio (1st prototype) has been completed and an early test is in progress during fall semester, 2003.

Creation of an embedded system to measure learning is highly ambitious. In the work funded by this proposal, our intent is to make progress and improvements on our present system. Thus, we anticipate that we will complete several pilot studies and establish some preliminary reliability and validity measures. Detailed reliability and validity studies are beyond the scope of the requested resources.

4.5 Project Evaluation

Project evaluation will follow the process outlined in NSF's user friendly guidebook. Our team believes in setting goals that are both meaningful and difficult to attain. We have developed a way for using the evaluation process to achieve these goals. Our plan is to:

a.) Set up three main project outcomes during the proposal preparation process.

b.) Soon after the grant is awarded, hire an external evaluator from the College of Education or the Institutional Research & Assessment Office (a campus office for institutional assessment). This person collaborates with us on all aspects of evaluation.

c.) As a team, generate a long list of concrete results that we might attain to provide evidence that we are reaching our outcomes.

d.) As the project begins moving, start creating and measuring results and organize these results into major categories that align with the project outcomes. Document all results up on a web-site.

e.) On a regular basis (e.g. once every 1-2 months), examine the results to date and compare these results with the major outcomes we want to achieve. Adjust the project plan to keep focus on creating the most compelling outcomes possible. Continually align small results so that they combine to create bigger results.

f.) Use the external evaluator to assess validity (are we really creating compelling outcomes?). To this end, we will expect our evaluator to show our results to others in order to establish the degree of validity and to establish that we are producing results that make the world a better place.

Step e is the key step—we try to align all project tasks so that they combine to create a coherent whole that is compelling. Central to this process is being brutally honest with the quality of results. It is easy to be very busy doing activities; however, creating meaningful results is hard and requires continual focus.

4.6 Dissemination

We anticipate that this project will generate substantive new knowledge. This knowledge will be disseminated to the engineering and education communities using the traditional venues: Internet, conference proceedings, and archival journal publication. Most of our dissemination will be at conferences: Frontiers in Education (FIE) and American Society of Engineering Educators (ASEE).

5. Project Plan

The project team, Table I, involves the four investigators plus a variety of other participants. Table II presents a detailed project plan that shows how project outcomes will be reached. We will be successful at a level that is commensurate with the resources that have been requested. We have a long history of innovation with little or no resources. That is, we are adept at stretching dollars. Moreover, we have carefully selected objectives that are reasonable extensions of our current and past activities. The proposed work will dramatically enhance and extend our two ongoing NSF-sponsored projects.

As usual, there are risks with this project. Our dominant risk is that we will not be able to involve enough faculty members because they are too overloaded and/or too firmly entrenched in the traditional ways of education. To minimize this risk, we will apply practices of effective change processes and we will be patient—our past experiences have helped us understand that we need to proceed "one faculty member at a time."

6. Benefits of the Proposed Work

Creative and Original Concepts. Edward DeBono invented the term 'lateral thinking' in 1967. In simple terms, lateral thinking involves **changing direction** instead of trying harder in the same direction. The proposed work is a change in the direction of conventional engineering and business education. Certainly, many elements of the proposed work have been achieved. However, we are creating this change over a large system comprised of two colleges.

Transfer. Transfer of the enterprise program to other contexts is highly important to us. Thus, we are designing our system with transfer in mind. Our on-line curriculum should be portable with little additional cost. In addition, we are working within traditional constraints (cultural and financial) that hamper many programs.

Enriched Learning. The enterprise program provides a environment and community that will help our young people grow into leaders and strong performers who intuitively think in an interdisciplinary fashion. We believe the long-term impacts will be enormous.

The Engineering Way. In addition to enriched educational outcomes, we are seeking to lower the cost of delivering education. In this time of shrinking budgets, efficient and effective education is becoming increasingly important. To innovate in a way that improves quality while decreasing costs is the engineering way. We believe we can attain our outcomes. As Eleanor Roosevelt stated, "***The future belongs to those who believe in the beauty of their dreams*** …."

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Table I People involved in the project		
Person	**Role**	**Responsibilities**
D. Elger	Project Leader	Manage overall project. Lead the portfolio project.
L. Morris	Project Co-Leader	Assist with project management. Lead the creation of three enterprises. Lead the Enterprise contest.
J. Morris	Core Team Member	Lead creation of the enterprise curriculum.
S. Beyerlein	Core Team Member	Facilitate newly formed enterprises so that they are successful.
D. Schlater	Liaison to the Center for Teaching Innovation.	Coordinate technical services for developing the internet courses.
To be identified	Faculty members (6) to advise enterprise courses	Advise enterprises
To be identified	Faculty members (8) to develop enterprise curriculum content	Detailed development of the enterprise courses.
To be identified	Project evaluator	Serve as external evaluator

Table II Project Schedule