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## THE INTERDISCIPLINARY DESIGN ENGINEERING DEPARTMENT: A SYSTEMS VIEW, A DESIGN FOCUS AND CUSTOMIZABLE INTERDISCIPLINARY TRACKS

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### ABSTRACT

Graduates of traditional engineering programs are called on to fill a myriad of interdisciplinary design careers that are increasingly different than historical engineering jobs. These careers focus on complex problems and the importance of solving them quickly in order to be successful corporately and nationally, and demand the use of teams of interdisciplinary, people-and-process-intuitive professionals with special technical skills in engineering systems and engineering design. The students who will be needed to fill these jobs are different as well. They have grown up with computers, have seen that emerging technologies occur at the interface or outside the boundaries of traditional disciplines and are diverse in many ways beyond gender and ethnicity. National trends show smaller percentages of high school graduates are now choosing careers in engineering. In this paper we report on a fresh and innovative type of engineering department that will offer programs carefully designed to augment traditional departments and programs while providing the underpinning engineering design and systems skills to attract and create the engineers needed today. This new engineering department, called **Interdisciplinary Design Engineering**, will produce graduates who are *experts in the process of designing engineering systems*.

### 1. INTRODUCTION: A NEW KIND OF ENGINEERING DEPARTMENT

If a university were to start a new engineering program today, from a clean slate, what should that program look like? What engineering and societal needs must its graduates prepare to face? Graduates entering the workforce face increasingly complex problems in a diverse, internationally-interconnected world undergoing rapid and unprecedented change. These complex problems demand the use of teams of interdisciplinary, people-and-process-intuitive professionals with special technical skills in engineering systems and engineering design. With their roots in

a specific engineering science discipline, traditional engineering departments typically do not provide the breadth needed to meet these systems-level challenges.

Smaller percentages of high school graduates are choosing careers in science, math, engineering, and technology (SMET) [1-3]. Is it because they see their grandparents' engineering department? Today's students are truly unique. They are digital, having grown up with computers, PDA's, and cell phones. They are diverse, having been exposed to many world views, languages, cultures, and styles. They are accomplished, having excelled in multiple extra curricular activities. *Many of these students would welcome the opportunity to customize a course of study that synthesizes their interests in engineering and science.*

In this paper we report on a fresh and innovative type of engineering department that will offer programs carefully designed to augment traditional engineering and science disciplines while providing the underpinning engineering design and systems skills to create the engineers needed today. This new engineering department, called **Interdisciplinary Design Engineering**, will produce graduates who are *experts in the process of designing engineering systems*. Moreover, the Interdisciplinary Design Engineering degree will provide considerable flexibility to students, allowing them to construct programs of study in areas of interest while maintaining a solid and rigorous foundation in mechanics, thermal science, electrical networks and linear systems.

We also address how an IDE department will mesh with existing departments within a large school of engineering. The systems and design components could stand alone as a department, but in order to offer interdisciplinary tracks of study (an important component, we believe), an IDE department needs other engineering departments. But do other departments need an IDE department? Moreover, do engineering schools need another engineering department? Establishing a new department requires resources; do the benefits of an IDE department outweigh the costs?

YEAR		MATH, SCIENCE & GENERAL EDUCATION	ENGINEERING FUNDAMENTALS	SYSTEMS & DESIGN	SPECIALIZATION
Freshman	fall	Math 14-Calculus 1 (4) Chem 4-Lab Safety (1) Chem 1/2-Chemistry 1 + lab (5) Gen Ed elective (3)	FE 10-Careers in Engineering (1)	IDE 20-Engineering Design (3)	
	spring	Engl 20-English composition (3) Math 15-Calculus 2 (4) Phys 23-Physics 1 (4)		Gen Ed-Economic Systems (3)	
Sophomore	fall	Math 22-Calculus 3 (4)	EE 151/152-Circuits I + lab (4) IDE 1xx-Stress Analysis+lab (4) Comp Sci Req (3)	IDE 105-Design Representations (3)	
	spring	Math 229-Elem. DE/Matrix Alg (3) Phys 24-Physics 2 (4) Gen Ed elective (3)	EE 153-Circuits II (3)	IDE 106-Design Perceptions (1) IDE 150-Dynamics of Systems (2)	
Junior	fall		CpE 111/112-Intro. Cp. Eng.+lab (4)	IDE 2xz-Linear Systems (3) IDE 210-Sys. Modeling/Prototyping (3) IDE 2xy-Thermal Systems (3)	Engineering focus (3)
	spring	Communication skills elective (3) Statistics elective (3)		IDE 215-Jr. Design Project (2) Emgt 361-Project Management (3)	Engineering focus (3) Engineering or Science focus (3)
Senior	fall	Gen Ed elective (3) Free elective (3)		IDE 220-Design Methodology (3)	Engineering focus (6)
	spring	Gen Ed elective (3) Free elective (3)		IDE 315-Interdisciplinary Design Project (3)	Engineering or Science focus (6)

Figure 1. IDE curriculum.

While some of these questions can only be answered with time, several key points can be addressed from the outset:

**Recruiting and retention benefit:** Students in Interdisciplinary Design Engineering have significant flexibility in choosing interdisciplinary tracks of study. This opportunity appeals to some progressive and broad-minded high school graduates today who may perceive existing engineering departments as too confining. Students already in college who begin in a traditional engineering department and discover that their interests are broad may also find a home in IDE rather than abandoning engineering.

**Ability to adapt to emerging technologies and the needs of local industry:** Many new companies, the ones driving the growth in the nation's economy, are creating and utilizing technologies that exist at the intersection of traditional disciplines. Most design projects in industry are now inherently cross-disciplinary, suggesting that extensive training in such an approach is vital. The kinds of technical personnel they need do not easily 'fit' in a single discipline. It is much easier for an agile, interdisciplinary department to offer specialized emphasis areas to meet particular industrial needs.

**Ability to incubate new degree programs:** Engineering deans can use a department like this to pilot or incubate a potential new degree program that will eventually become housed in its own stand-alone department. For example, on our campus, the faculty of the chemical engineering department is facing several challenges in defining and starting a biological engineering program. Such a program could be incubated within an IDE program where the more flexible curriculum would allow different course tracks to be tested before defining a permanent program.

**A meeting ground, a catalyst, for interdisciplinary work:** A department like this, at its core, will be interdisciplinary; it will depend on other departments. It will also provide a meeting ground and be a vehicle to foster communication and collaboration between engineering colleagues in different departments. This department will feed students into the classes of the traditional programs. Faculty from traditional programs will help create the needed interdisciplinary tracks. Senior design projects will

be shared with existing departments and joint research will be pursued.

## 2. THE INTERDISCIPLINARY DESIGN ENGINEERING PROGRAM

Specifically, the IDE department will prepare graduates to use modern design methodologies, simulation, analysis, and optimization techniques within a team-based learning environment to develop safe and functional solutions to complex interdisciplinary design problems (i.e., systems) while adhering to systems constraints involving economics, reliability, durability, aesthetics, ethics, and social impact (including legal and environmental issues).

The Interdisciplinary Design Engineering (IDE) department and its curriculum, shown in Fig. 1, provide an opportunity for students and faculty to create a distinct culture, community and identity. By fostering interdisciplinary studies, it will be inherently agile and adaptive, giving students the flexibility to choose – and even design – interdisciplinary specialties that match their interests and motivation.

The curriculum will lead to an Accreditation Board for Engineering and Technology (ABET) accredited Bachelor of Science degree in Interdisciplinary Design Engineering. The foundation of the curriculum is laid in the first two years with math, science, general education, and engineering fundamentals courses. Three IDE courses in the design area tie these foundational courses together in both the freshman and sophomore year. In the junior and senior years, the focus of the curriculum shifts toward design, engineering systems, and specialty track courses. Also, several general education electives, including two free (in terms of discipline) electives, are included.

### 2.1 Planning Grant Results: Defining the IDE Program

An NSF planning grant (EEC-0230088) supported the creation of this new curriculum. As part of the grant, the IDE curriculum was shaped through completion of seven tasks: 1) customer needs were gathered, where our customers consisted

of potential students and potential employers of IDE graduates; 2) related programs and approaches were surveyed (e.g., [4, 5]); 3) ABET requirements for the proposed degree were studied; 4) specialty track guidelines and defined sample tracks were formulated; 5) modern design methods were employed to link customer needs to a desired curriculum; 6) educational software available to support the IDE program was investigated; and 7) the proposed IDE curriculum was reviewed by three external experts [6]. Key results of the planning grant tasks are presented in the remainder of this section.

**Understanding the Customer.** Engineering degree preferences of high school seniors in Missouri and surrounding states were investigated, and these findings are summarized in Table 1 [6]. A substantial number of high school students expressed an interest in non-traditional engineering degrees. Combining those students expressing an interest in majors of (a) engineering science, (b) other engineering technologies, (c) general engineering, and (d) general engineering-related technologies, a pool of 2,921 potential students (with an average ACT score of 28.7) was found from Missouri and its border states. However, in the Fall 2001 semester, only 78 students from this pool enrolled at UMR.

**Table 1. ACT results for Missouri and surrounding states (AR, IL, IA, KS, KN, NE, OK, TN) for graduating class of 2001.**

Educational major	ACT test sample	ACT average	UMR yield
Engineering science	8	28.4	0
Other engineering technologies	43	28.1	1
General engineering	2244	28.8	60
General engineering-related technologies	626	28.6	17

To determine if our perceived need of a broadly educated engineer able to work at the boundaries of two traditional engineering disciplines is supported by industry, we gathered and analyzed customer needs [7]. We solicited the needs from three industry advisory councils, a pool which represents automotive, appliance,

industrial equipment, electronics and energy companies as well as government and military labs. Responses were used to generate an initial set of customer needs for the degree program and are summarized in Table 2. The list of needs is weighted based on the frequency with which they occurred in the responses. One need emphasized (and receiving a top weight) is to ensure that interdisciplinary engineering graduates have an appropriate depth of engineering skills regardless of which two traditional engineering fields provide their breadth. This need complemented our desire to create a broad-based engineering degree that augments students' technical prowess.

In addition to the free response questions, a prepared set of questions was utilized to determine industry interest in hiring an IDE graduate (a description of the proposed program was provided to the respondents). The survey questions used a Likert scale. All questions garnered a response that was greater than neutral in terms of support for an IDE program as shown in Table 3. For example, several respondents said the program was a good approach to bridge the gaps between traditional engineering programs and to prepare engineers for the workforce. In particular, most industry representatives reported that their company produced products involving multiple engineering domains (question 3) and they were slightly more likely to hire an IDE graduate than a traditional engineering graduate (question 5). The respondents were all technical professionals that were in a position to influence hiring policy at their company. The sample size for the survey was 18.

**Benchmarking Other Programs.** A survey of programs related to interdisciplinary design engineering was completed in order to gain ideas and further assess needs. The survey included local programs in Missouri and surrounding states as well as other programs in the US and abroad. The information collected on these programs includes ABET accreditation status (US programs), a measure of the flexibility of the programs in terms of engineering and science electives (free and restricted), and the number of courses that contain a significant engineering design component. Table 4 shows the results of this survey for a representative

**Table 2. Top weighted customer needs (> 1) gleaned from industry surveys (5 = most important, 1 = least important).**

Customer need	Wt.	Customer need	Wt.
Possess sound engineering technical skills	5	Understand project management techniques	4
Generate creative solutions	5	Flexibility in course selection	4
Possess knowledge of multiple engineering domains	4.5	Possess prototyping skills	3.5
Curriculum contains design content	4	Emphasize conceptual design	3
Students are able to work in teams	4	Know how to gather customer needs	3
Know how engineering fits with other organizational functions	4	Able to plan and facilitate meetings	2
Communication/presentation skills	4		

**Table 3. Industry interest in IDE skill set and graduates.**

Question	Response range	Avg. resp.
1. Does your company have a need for engineers that are broadly educated across several disciplines?	[1=Not at all, 7=Yes, in all cases]	5.15
2. Do the engineers who design products in your company use a systematic design methodology, such as QFD, design for six sigma, FMEA or other approach?	[1=Not at all, 7=Yes, in all cases]	4.85
3. Do the products your company produce involve multiple engineering domains (such as mechanical and electrical)?	[1=Not at all, 7=Yes, in all cases]	6.15
4. Based on the program description, does this interdisciplinary engineering program provide the key skills that your engineering employees need?	[1=Not at all, 7=Yes]	4.92
5. Would you be more likely or less likely to hire a graduate of this interdisciplinary engineering program than from a traditional engineering program?	[1=Less likely, 7=More likely]	4.31
6. How important is it to your company to hire graduates from an ABET accredited engineering program?	[1=Not at all, 7=Extremely important]	6.15

**Table 4. Survey of Programs Related to Interdisciplinary Engineering**

University	Degree	ABET (IP = in progress)	Free Eng. Courses	Restricted Eng. Elect	Sci/Math Elec.	Design Courses
Cardiff University, England	Integrated Engineering		0	4	0	7
Grand Valley State University, Michigan	Engineering	yes	7	2	6	7
New Mexico Highlands University, New Mexico	Engineering	IP	3	0	0	5
Purdue University, Indiana	Interdisciplinary Engineering	no	21	0	2	0
Smith College, Massachusetts	Engineering Science	IP	3	0	2	2
Stanford University, California	(Indiv. Designed Majors)	no	12	1	12	7
University of Aberdeen, Scotland	Integrated Engineering	N/A	0	9	0	7
University of Denver, Colorado	General Engineering	yes	4	0	0	7
University of Florida	Engineering Science	yes	7	0	0	5
Univ of Illinois - Urbana-Champaign	General Engineering	yes	4	2	0	7
University of Missouri-Rolla	Interdisciplinary Design Engineering	IP	7	0	1	7
University of Newcastle, Australia	Mechatronic Engineering	N/A	1	3	0	4

<p><b>MECHATRONICS</b>                      IDE 3xx Reverse Engineering and Design Modeling                      CpE 317 Fault-Tolerant Digital Systems                      CpE 213 Digital Systems Design                      ME 279 Automatic Control of Mechanical Systems                      ME/AE/EM/EE 329 Smart Materials and Sensors                      EE 253/255 Electronics I                      EE 205/208 Electromechanics                      EE 235 Controllers for Factory Automation</p>	<p><b>ENERGY SYSTEMS AND THE ENVIRONMENT</b>                      CvE 230 Fluid Mechanics                      CvE 261 Intro. to Environmental Engineering                      CvE 367 Intro. to Air Pollution                      EE 207 Power System Design &amp; Analysis                      EE 304 Power Quality                      EE 307 Power Systems Engineering                      EMgt 345 Energy Management Engineering</p>
<p><b>PRODUCT DESIGN</b>                      Met 121 Metallurgy for Engineers                      Met 221 Principles of Materials Processing                      EE 205 and EE 208 Electromechanics and lab                      EMgt 311 Human Factors                      ME 208 Machine Design I                      ME 213 Machine Dynamics                      ME 279 Automatic Control of Mechanical Systems                      or ME 307 Vibrations</p>	<p><b>ENTERTAINMENT ENGINEERING</b>                      CSc 345 Intro. To Robotic Systems                      EE 267 Linear Systems II                      EE 323 Classical Optics                      EE 345 Digital Image Processing                      ME 213 Machine Design                      ME 349 Robotic Manip. &amp; Mechanisms                      Min 309 Commercial Pyrotech. Ops.                      or ME 309 Engr. Acoustics</p>

**Figure 2. Four specialty tracks that may be immediately implemented within the IDE curriculum.**

sample of the programs examined. This information was gathered primarily from university web sites and published course descriptions, which may or may not be continuously updated as programs evolve.

Note that many of the programs in Table 4 are located outside the US, while just a few can be considered to be local (Missouri and surrounding states). The UMR IDE program has a strong design component (7 courses) and a significant number of free engineering electives (7 courses), as compared to other universities in our region.

External Reviews. The customer needs summarized in Table 2 served as input to a Quality Functional Deployment (QFD) analysis [8-10]. The output of this exercise was the proposed set of courses that define the IDE curriculum. A review of the proposed IDE program, held at UMR in June 2003 by three external experts from interdisciplinary engineering and design fields, led to the IDE curriculum shown in Fig. 1. The resulting curriculum offers three opportunities: 1) to provide flexibility to the student in the selection of an engineering focus (typically at the boundaries of two or more traditional engineering disciplines); 2) to reassess the viability of age-old courses in today’s environment and reform course offerings; and 3) to give the student clear competency in

understanding multi-domain engineering products. These opportunities are described next.

Flexibility. The IDE curriculum features specialization “tracks” that allow students to tailor their education to meet their interests and that enable the department to respond to emerging, cutting-edge engineering fields. For example, our university does not currently have a way to provide *undergraduate* emphasis areas in such cutting-edge and emerging fields as nano- or bio-engineering or entertainment engineering [11]. Even more established areas as mechatronics or micro-electromechanical systems (MEMS) suffer the same difficulty at the undergraduate level. In areas such as mechatronics and MEMS the specialty tracks provide a way to utilize existing technical electives from different departments to meet that need. In the emerging fields (such as nano- or bio-engineering), the tracks support more unconventional approaches to providing courses in the area by utilizing industry or lab researchers to provide content in a more flexible format when limited UMR expertise is available. Example tracks that can be implemented immediately include mechatronics, product design, energy systems and the environment, robotics and control and entertainment engineering. Four of these tracks are shown in Fig. 2. To accommodate more diverse student interests and respond

to emerging interdisciplinary engineering fields, new tracks may be defined as long as they consist of at least 21 credit hours, give significant exposure in two or more areas of engineering or science, consist of at least 12 credit hours of engineering and include at least three credit hours of advanced technical elective.

Course Reform. We face contradictory constraints related to course reform: maintain technical rigor while reducing the number of required credit hours. (UMR has set 128 credit hours as its new standard for engineering degrees, comparable to other top-50 engineering programs.) In the IDE curriculum, we are eliminating the repetitive topics in some courses and combine the remaining topics into cohesive courses. In particular, we combine the Statics and Mechanics of Materials courses (a total of seven credit hours) into an Introductory Stress Analysis course for four credit hours. Traditional Thermodynamics and Heat Transfer courses will be combined into a Thermal Systems course. We update our old Dynamics course by removing topics previously covered in physics and adopting a more general dynamics of systems approach. In all instances, the major benefit of course reform is a shift from courses emphasizing isolated topics to courses placing these topics in a broader, systems context.

Core Competency in Interdisciplinary Design Engineering. The fundamental focus of the new IDE program is on principles of engineering systems and engineering design. Accordingly, these principles are integrated into each year of the degree program. The Engineering Design course in the freshman year gives an immediate engineering design experience to all engineering freshmen at UMR. It also introduces students to project management and teaming skills. Though freshman design courses are increasingly commonplace across the US, our implementation is noteworthy in its interdisciplinary nature (a product of the campus' common freshman year for engineering students). The sophomore-level Design Representations course will provide depth to identifying, representing and communicating important elements of design concepts. This will include not only computer applications (e.g., solid modeling), but also strengthen fine arts skills (e.g., sketching, sculpting, photography) and communication skills (e.g., presentations, oratory, written documentation). As a complement to the Design Representations course, a sophomore-level Design Perceptions seminar will provide students with exposure to contemporary interdisciplinary research and design issues. A junior-level design project course is included to give students an avenue to actively experiment with their most recent engineering/science electives in a design context. In the senior year, the two design courses will formally define the design process and incorporate industry standard design and planning tools.

Likewise, engineering systems courses are distributed throughout the four year IDE program. The first exposure is a systems view of economics in the freshman year, designed to give a broader view of economic principles than the traditional micro or macro versions. In the sophomore year, a Dynamics of Systems course is required. The bulk of the systems courses are offered during the junior year. A new Linear Systems course will be developed to provide coverage of linear systems in multiple engineering domains, and a new Systems Modeling and Prototyping course will introduce modeling, simulation, and prototyping of mechatronic systems, including the concept of

virtual prototypes. A reformulated Thermal Systems course, as described previously, completes the junior year systems courses. Finally, a Project Management course is required to complement the capstone design courses.

## **2.2 A Special Culture: Creative, High-Energy, Diverse and Supportive**

In addition to the program specifics, the IDE department fosters a special culture of creative, high-energy, diverse and supportive persons, including students, staff and faculty. To support that culture, the IDE department will be markedly different from traditional engineering departments in three key areas: 1) pedagogy; 2) student-faculty interaction; and 3) physical environment.

### **2.2.1 Pedagogical Reform**

Undergraduate engineering pedagogy has long divided learning activities into lecture and laboratory courses, with lecture courses greatly outnumbering lab activities. Learning theories and studies on learning and teaching styles indicate that integrated lecture and laboratory activities are better suited for complete learning [12-16]. Most college education is geared toward abstract conceptualization, but complete learning is enhanced by the use of all of the processes [14]. To access different learning styles, hands-on work must be added to the traditional lecture format. Engaging pedagogy is strongly associated with improved learning outcomes [17].

Incorporating Labtutes. The IDE department will use "labtutes," a course format akin to the studio model in liberal arts programs, where hands-on activities with existing products are incorporated, as much as possible, into the lecture environment. This approach supports the SMET educational practices already developed by Bransford [18] and Brereton [19]. For each topic covered, a concrete experience is used to motivate the class discussion. During the class, interactive segments are planned for every 7-11 minutes to keep the students involved [20, 21]. These segments may be as simple as having students pair up and work part of an example problem or more orchestrated efforts such as planting questions with students that they ask at the correct moment. The theoretical development, focusing on the fundamental behavior of physical systems, and a detailed problem solution procedure are treated succinctly. A meaningful example problem is then worked out to illustrate the solution procedure. Finally, a hands-on experience with a product is provided for active experimentation.

Student Portfolios. Students build design portfolios as they progress through the IDE curriculum. Design projects from IDE and other courses will be showcased in portfolios as a means of documenting student accomplishment. The concept of student portfolios will be formally introduced in the sophomore level Design Representations course. Each year, the department holds a "design exhibit," analogous to an art studio exhibit, where students will display elements of their portfolio. This activity will be particularly beneficial to freshmen and sophomores so they may see what opportunities (and challenges) lay ahead. Another obvious benefit of the portfolios is as an aid at job interviews. The portfolios will also be a central component of the assessment

Year	Department Culture and Course/Program Development	Faculty Development and Teaching Innovations	Assessment and Continuous Improvement
Phase 1	<ul style="list-style-type: none"> <li>•Department web page: design tools</li> <li>•Develop plan for department diversification</li> <li>•Advertise for visiting professors/researchers</li> <li>•Teach IDE 105 Design Representations</li> <li>•Develop technical elective course in "3-week semester" format (visiting expert)</li> <li>•Teach IDE 106 Design Perceptions</li> <li>•Insert PRS in IDE courses</li> <li>•Develop IDE 214 Systems Modeling/Prototyping</li> <li>•Develop IDE 215 Jr. Design Project to include service learning projects</li> </ul>	<ul style="list-style-type: none"> <li>•Forge relationships with industry</li> <li>•Develop faculty evolution plan</li> <li>•Finalize curriculum evolution plan</li> <li>•Two new faculty: design &amp; mechanics backgrounds</li> <li>•Forge relationships with UMR's engineering/science departments</li> <li>•Plan Faculty Workshop series</li> <li>•Develop team training units</li> <li>•Develop Agreement with SDEL</li> <li>•Forge relationship with Ft. Wood</li> <li>•Faculty Workshop: teamwork</li> <li>•Visiting Expert</li> </ul>	<ul style="list-style-type: none"> <li>•Fine tune overall program assessment with CERTI</li> <li>•Create Student Advisory Comm. (SAC)</li> <li>•Create Faculty Advisory Comm. (FAC)</li> <li>•Create Industry Advisory Comm. (IAC)</li> <li>•Initiate ABET evaluation study</li> <li>•Assess student portfolios &amp; feedback</li> <li>•Receive SAC, FAC, IAC reports</li> <li>•Survey industry sector needs &amp; feedback</li> <li>•Update overall assessment plan w/ external components</li> <li>•Develop teamwork assessment plan</li> </ul>
Phase 2	<ul style="list-style-type: none"> <li>•Teach IDE 214 Systems Modeling/Prototyping</li> <li>•Begin design of IDE environment (students and faculty)</li> <li>•Offer a engineering specialty track course in "3-week semester" format</li> <li>•Teach IDE 215 Jr. Design Project</li> <li>•Develop IDE 1xx Introductory Stress Analysis</li> <li>•Teach IDE 1xx Introductory Stress Analysis</li> <li>•Develop IDE 2xy Thermal Systems</li> <li>•Teach IDE 2xz Thermal Systems</li> </ul>	<ul style="list-style-type: none"> <li>•New faculty: design background</li> <li>•Faculty Workshop: design tools</li> <li>•Forge relationship with UMR's CERTI (Center for Educational Research &amp; Teaching Innovation)</li> <li>•Visiting Expert</li> <li>•Plan Department seminar series (expert lectures)</li> <li>•Faculty Workshop: active learning</li> <li>•Visiting Expert</li> <li>•Work with Econ. department to develop new course (Economic Systems)</li> </ul>	<ul style="list-style-type: none"> <li>•Plan faculty/student seminar series (assessment, mentoring, networking)</li> <li>•Create course assessment plan</li> <li>•Create faculty teaching assessment plan</li> <li>•Conduct Self Evaluation of Program I &amp; feedback</li> <li>•Assess student learning modes &amp; feedback</li> <li>•Assess student attitudes &amp; feedback</li> <li>•Assess faculty attitudes &amp; feedback</li> <li>•Conduct External Evaluation I &amp; feedback</li> <li>•Finalize overall assessment plan w/ internal components</li> </ul>
Phase 3	<ul style="list-style-type: none"> <li>•Modify dynamics course (systems perspective)</li> <li>•Teach new dynamics course</li> <li>•Develop IDE 2yz Linear Systems</li> <li>•Teach IDE 2xz Linear Systems</li> <li>•Develop plan for St. Louis IDE program</li> <li>•Implement St. Louis IDE program</li> </ul>	<ul style="list-style-type: none"> <li>•New faculty: systems background</li> <li>•Faculty Workshop: projects</li> <li>•Develop workshop to disseminate results of this work</li> <li>•Visiting Expert</li> <li>•Plan future faculty workshops</li> <li>•Update department seminar plan</li> <li>•Visiting Expert</li> <li>•Faculty Workshop: teaching</li> <li>•Offer workshop to disseminate results</li> </ul>	<ul style="list-style-type: none"> <li>•Assess new courses</li> <li>•Survey industry needs &amp; feedback</li> <li>•Create advising assessment plan</li> <li>•Assess advising &amp; feedback</li> <li>•Conduct Self Evaluation of Program II &amp; feedback</li> <li>•Conduct External Evaluation II &amp; feedback</li> <li>•Update overall assessment plan</li> </ul>

**Figure 3. Implementation Plan of the IDE program.**

process, and will therefore have multiple uses.

### **2.2.2 Student-Faculty Involvement.**

The IDE department will encourage student-faculty interaction at the classroom, research and social levels. The labture learning environment described previously encourages interaction between students and faculty as students grapple with new material. Undergraduate students will be encouraged to participate with faculty in their active research, or define their own topics. We envision periodic picnics, brown-bag lunches and/or late afternoon pizza gatherings of students and faculty. We plan periodic seminars we call "Systematics" where current topics of design, systems, industrial practice, research, entrepreneurship, or human events, will be the focus. Some of these seminars will be called "System-Antics," where students or faculty may present drama, music, comedy, readings, or other works of performance art. We also will provide opportunities for students to display other types of art. We strongly believe that the well-rounded student, faculty member and engineering department should foster the arts and personal development in areas other than hard science.

### **2.2.3 The Physical Environment**

Our vision of a new kind of engineering department involves

not only a new curriculum and fresh approaches to teaching and learning, but also the creation of physical spaces that make a statement that this is a special, creative, dynamic, welcoming place for students and faculty to learn and interact. We envision brightly colored rooms, design projects on display – even hanging from ceilings – artwork, comfortable and stylish chairs and furniture, student and faculty commons area(s), music where appropriate, availability of scratch pads, dry boards and writing implements for impromptu brainstorming, cutting edge computer labs, wireless networks and laptops, classrooms set up to accommodate team activities, and many other special features. For instance, in the Fall 2004 semester, the freshman Engineering Design students painted a "team square" on the floor of the team meeting area as part of a project management and team building exercise. We seek to create a departmental culture where creativity is sparked, developed, and released as much as possible. We believe that underrepresented students will be preferentially attracted to a department with this kind of atmosphere.

## **3. IMPLEMENTING THE IDE DEPARTMENT AND DEGREE PROGRAM**

The Interdisciplinary Design Engineering Department has evolved from a service department, formerly named Basic



**Figure 4. Students enrolled in an experimental interdisciplinary design course sequence present their “Smart Marker” projects to the US Army (May 2002).**

Engineering, into the degree-granting department described in Section 2. The program launched in Fall 2005 with the first class of sophomores entering the IDE program. The initial version of the program will utilize primarily existing courses in order to get the program underway with minimal development effort. UMR already has a common freshman year for all engineering students, so no changes are made at that point. The sophomore year will contain two new courses specific to the IDE program – one of these is a one credit hour course covering contemporary issues in interdisciplinary research and design. The junior year will also contain two new courses, one of which is a project based course. Likewise, the senior year contains two courses specific to the program, but these courses have already been developed and taught, so in reality there are only four new courses which must be developed in order to offer the program. This strategy of minimal new courses was chosen for a very simple reason; there will be few new resources available to begin the new program. UMR tends to award resources based on enrollment and teaching load, so it is anticipated that as enrollment grows new resources will be provided for further development of specific courses to be taken by IDE majors. These courses will aid in providing an interdisciplinary, systems flavor to the program.

In Fig. 3, three implementation phases for the IDE program are shown. Each phase is broken into three categories that are addressed in parallel: departmental culture and program development; faculty enrichment and teaching innovations; and assessment and continuous improvement. It is our view that these three areas are critical to the success of the new IDE program. Each of the three phases corresponds to a one to two year time period. The exact timeframe depends upon student enrollment growth and its associated increase in state resources. In this section, we address the program development and department culture, including the important evolution of our physical environment.

### **3.1 Program Development: Continued Evolution**

Trial Run. A few years ago, faculty in the department completed a project in cooperation with the US Army involving the incorporation of a funded design project into an interdisciplinary senior design sequence [22, 23]. A total of 15 students participated in the two-semester course sequence, forming three teams that produced prototype “smart markers” for the Army. Mechanical, electrical and computer engineering students as well as engineering management students participated, shown in Fig. 4 with their projects. All parties involved in this experimental offering (stu-

dents, faculty, the campus and the Army) considered the project to be highly successful. These two existing interdisciplinary design courses will anchor the senior year of the new curriculum.

Phase 1. During the first phase (the current time period), we teach the new Design Representation and Design Perceptions courses. The two new courses have been defined in the spring and summer semesters of 2005 and are currently being offered (Fall 2005 and Spring 2006). The two junior-level courses (Systems Modeling/Prototyping and Junior Design Project) will be developed as well. At the end of phase 1, a snapshot of the IDE curriculum looks as shown in Fig. 5 (a). This phase also sees two new faculty joining the department and initiation of the IDE assessment plan. Note that in Fig. 5, boxed courses are newly developed or reformulated and pink highlighted courses remain to be completely developed (initial course objectives and outlines are prepared, however). Green, underlined courses are “borrowed” from other departments and serve as an adequate substitute during the transitional time.

Phase 2. The second phase of implementation is our most ambitious in terms of course development. The Statics and Mechanics of Materials courses will be combined into a new Introductory Stress Analysis course and taught during this phase. This reformulation frees up three credit hours and allows us to add a Project Management course to the curriculum (a need uncovered from our industrial advisory councils). The previously borrowed Thermal Analysis course will be reformulated as Thermal Systems in collaboration with the mechanical engineering department. Beyond our departmental lines, we will work with the economics department to develop an Economic Systems course that will replace one of the required general education elective courses during the freshman year. The curriculum, as it will look at the end of phase 2, is shown in Fig. 5 (b).

Phase 3. In the final implementation phase, the remaining “borrowed” Linear Systems course will be replaced by an IDE course. The traditional Dynamics class will be reformulated to include a systems view of dynamics in addition to traditional Newtonian mechanics topics. The final IDE curriculum is shown in Fig. 5 (b). During Phase 3, we also expect to begin delivery of the IDE curriculum through our satellite campus, the UMR Engineering Education Center (EEC), located on the campus of Univ. of Missouri-St. Louis. Initially, IDE faculty will deliver our IDE courses at the EEC either remotely or in person. Other fundamental courses will be taught by EEC faculty or faculty at a partner institution. St. Louis students will complete the specialty

Freshman Year				Freshman Year			
BE10; IDE 20; Chem 1, 2, 4; Engl 20; Math 14, 15; Phys 23; Hist/Pol. Sci. elect.; Econ. elec.		31		BE10; IDE 20; Chem 1, 2, 4; Engl 20; Math 14, 15; Phys 23; Hist/Pol. Sci. elect.; <u>Economic Systems</u>		31	
Sophomore Year				Sophomore Year			
IDE 105 Design Representations	3	EE 153 Circuits II	3	IDE 105 Design Representations	3	EE 153 Circuits II	3
Math 22 Calculus III	4	IDE 106 Design Perceptions	1	Math 22 Calculus III	4	IDE 106 Design Perceptions	1
EE 151 Circuits I	3	IDE 150 Dynamics	2	EE 151 Circuits I	3	IDE 150 Dynamics	2
EE 152 Circuit Analysis Lab I	1	IDE 110/120 Mech. of Matl. + Lab	4	EE 152 Circuit Analysis Lab I	1	Humanities Elective	3
IDE 50 Statics	3	Math 229 Elem. DE & Matrix Algebra	3	IDE 1xx Introductory Stress Analysis	4	Math 229 Elem. DE & Matrix Algebra	3
Computer Sci. Requirement	3	Phys 24 Engineering Physics II	4	Computer Sci. Requirement	3	Phys 24 Engineering Physics II	4
	17		17		18		16
Junior Year				Junior Year			
EE 265 Linear Systems	3	Communications Skills Elective	3	EE 265 Linear Systems	3	Communications Skills Elective	3
IDE 210 Systems Modeling/Prototyping	3	Engineering/Science Elective	6	IDE 210 Systems Modeling/Prototyping	3	Engineering/Science Elective	6
CpE 111/112 Intro. Cp. Engr. + Lab	4	IDE 215 Jr. Design Project	2	CpE 111/112 Intro. Cp. Engr. + Lab	4	IDE 215 Jr. Design Project	2
Engineering/Science Elective	3	Humanities Elective	3	Engineering/Science Elective	3	Emgt 361 Project Management	3
ME 227 Thermal Analysis	3	Statistics Elective	3	IDE 2xx Thermal Systems	3	Statistics Elective	3
	16		17		16		17
Senior Year				Senior Year			
IDE 220 Design Methodology	3	IDE 315 Interdisc. Design Project	3	IDE 220 Design Methodology	3	IDE 315 Interdisc. Design Project	3
Engineering/Science Electives	6	Engineering/Science Electives	6	Engineering/Science Electives	6	Engineering/Science Electives	6
Free Elective	3	Gen Ed Elective	3	Free Elective	3	Gen Ed Elective	3
Gen Ed Elective	3	Free Elective	3	Gen Ed Elective	3	Free Elective	3
	15		15		15		15
Legend:				Legend:			
<u>First-time taught</u>		Borrowed courses		<u>New/Reform. courses</u>		Borrowed courses	
		Under development		Added course		TBD courses	
(a)				(b)			

Figure 5. Snapshots of the IDE curriculum after (a) Phase 2 and (b) Phase 3 activities. Note that the common freshman year is abridged for brevity.

tracks through a combination of remote UMR courses and EEC-taught courses.

#### 4. ASSESSMENT AND CONTINUOUS IMPROVEMENT

The structure of the department is based partly on input from outside sources, especially from industry, concerning the need for innovative new approaches to attracting and educating students in STEM fields. A considerable need exists to better align educational practices with industry practices, and the Interdisciplinary Design Engineering curriculum is intended to do just that. One of the innovations in IDE is the use of “customer input” in all facets of the program’s design and function. Industry feedback is being incorporated into the program’s design, and we are beginning to seek student and faculty input toward the same goals. The process of assessing user needs, views, satisfaction, and outcomes is an integral part of the strategic plan for IDE; our belief is that this department must have input from those affected by and participating in its programs.

The groups from whom we have sought and will continue to seek feedback are employers and other industry representatives, out-of-department faculty in the three schools and the College of Arts & Sciences on campus, prospective students and students enrolled in the department, and IDE faculty. Regular assessment of our educational processes will take place within each course using an early and frequent feedback model employing classroom assessment techniques as suggested in Angelo and Cross [24]. Faculty in other departments in which IDE students take courses will be encouraged to use these processes as well. This assessment information will be used in “real time” to ensure that learning objectives are being met. Following the conclusion of each semester, the IDE faculty will review the changes made in all courses for possible modifications to the course descriptions. Up-to-date course descriptions and course syllabi will be needed to ensure reasonable consistency of practice.

Extensive use will be made of collaborative, active learning modalities that will increase student engagement [25]. These methods will be designed to make systematic use of assessment data from students, both individually and in learning groups. Similar assessment mechanisms will be employed to develop and maintain an advising program to help ensure that IDE advising is a highly functional process. Although student evaluations of faculty instruction will be used in IDE, as in other departments, we wish to move away from an over-reliance on a single source of data regarding faculty performance that has not proven to be helpful in correcting instructional process problems.

Student learning outcomes are the key concern of our assessment efforts. Toward that end, we will utilize portfolio assessment as the principal assessment tool. Faculty will be trained in portfolio development and evaluation methods, and we will utilize trained students as “portfolio consultants” as well. Note that a portion of the second semester sophomore new IDE course will be devoted to portfolio development. The learning objectives to be assessed, in addition to course content, are in areas such as collaborative/team-based learning skills, self-efficacy, self-confidence, and intentions toward lifelong learning. We will also make use of traditional measures such as GPA, exam and quiz scores, homework performance, etc. These performance indicators will be used in a more dynamic framework using other measures as indicated above. This approach will be more consistent with the structure and goals of this department.

New IDE faculty will be selected in part based on their desire to participate in this more active approach to facilitating student learning. A significant component of the faculty evaluation process will be the thoroughness with which faculty collect and utilize student assessment data in the courses they teach. The expectation is that all faculty will “close the loop” in making use of assessment data for both instructional and advising improvement. It is further expected that IDE faculty will model good instructional

and advising practice for other faculty and will share these models with faculty in other departments.

If this dynamic new department is to meet its promise, we believe it is imperative that our instructional and evaluation processes reflect the systems perspective upon which the department is founded. Our assessment mechanisms, therefore, will be designed with this belief firmly in mind.

## 5. CONCLUDING THOUGHTS

The new Interdisciplinary Design Engineering department described here is a response to the important research topics and disciplines that have emerged from over two decades of engineering design research by the DETC community. It is our belief that the theory, principles and methods that underpin engineering design transcend any one traditional engineering discipline or department. This belief, bolstered by a customer needs analysis of industry, government labs and students, has led us to create the new IDE degree program that fosters careers in the broader engineering design field.

Modern design methods were employed to link customer needs to curricular elements in the development of the Interdisciplinary Design Engineering program described in this paper. During the next several years, we will continue to use design methods to drive continued evolution of the program in response to changing customer needs. Thus, the same tools that will be taught in our new design classes have been used by faculty in developing the new curriculum. The strong design content of the new curriculum will set our students apart from graduates of traditional engineering programs.

The Interdisciplinary Design Engineering program will also have a significant impact on the knowledge on learning of engineering. The core contribution we hope to make is actually an admission – we cannot teach students everything they need to know about engineering. Instead, the IDE program focuses on teaching students to develop the skills necessary to “learn on demand.” Design theory, as the backbone of the IDE program, supports this pedagogical change by prescribing how to identify a problem, understand it, search (learn) for solutions, evaluate alternatives and embody a solution. More specifically, we expect to disseminate how decades-old engineering science courses can be reformulated to remove repetitive topics and instill in students the ability to delve into greater detail as needed.

The Interdisciplinary Design Engineering department at UMR will meet the emerging societal and educational needs of the 21st century. Higher education learning environments increasingly must be active, accessible, accountable and responsive. Engineering programs, in particular, must be designed with these principles in mind if they are to have any chance of attracting larger numbers of students, especially students who have traditionally been underrepresented in engineering. The IDE department has the potential to lead the way to achieving these objectives, not just at this institution, but to serve as a positive example for other SMET-focused programs and institutions as well.

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