Session 2357

Tools for Early Discipline Integration of Industrial Engineering and Business Students

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1. Introduction

In practice, Industrial Engineers are often tasked with appropriately implementing developing technology within an organization's business model. This integrating role requires interaction with technical specialists (engineers) and business management. Some universities are emulating this environment for teaching in the senior year through adoption of multidisciplinary senior design projects. Additionally, most industrial engineers have experience interacting with other engineers earlier in their academic career through common engineering courses. However, interaction with business students rarely occurs before the senior year, if then. This deficiency prevents the development of a key skill required for industrial engineering practice.

This paper describes two innovative approaches to experientially teach multidisciplinary problem solving to teams of engineering and business students. Both approaches allow the interactions to occur earlier in the curriculum. The first approach is through class partnering. Such partnering emulates more long term interdisciplinary efforts such as design teams and configuration management teams. This approach involves the association of one business class with an industrial engineering class. Multidisciplinary teams work throughout the semester to solve a realistic problem associated with a single product or system, organized to culminate in a technical design and implementation appropriate for a given business model. This approach has already been tested using a product realization project involving student from two classes, an International Management class from the Department of Business Administration (School of Business and Economics), and the Computer Aided Design and Manufacture course from the Department of Industrial & Systems Engineering (College of Engineering). Best practices and likely challenges are listed.

Based on challenges from the class partnering approach, a second approach is describe which uses the Active Learning In the Virtual Enterprise (ALIVE) system. This approach emulates shorter term interdisciplinary efforts common in Industrial Engineering practice. The Virtual Enterprise (VE) is a full scale manufacturing supply chain, integrated using information technology, and producing an actual product (desk clocks). Departmental laboratories are organized as business departments within the enterprise. ALIVE is a set of web-based learning modules, essentially short internships in different areas of the VE. ALIVE provides a practical and consistent means of developing realistic problem solving skills in engineering and business students reaching a variety of learning styles. This second approach is described along with expected benefit and challenges.

2. Background

2.1 Engineering Education

The nature of engineering practice has changed significantly over the last three decades. The pace of change, driven by increased competitive pressures, has been particularly intense over the last decade. However, engineering education has not changed appreciably over that period. The growing gap between traditional engineering education and the result of many years of change in engineering practice has caused engineering school constituents to question the effectiveness of the programs[1]. Graduate engineers are expected to contribute immediately in competitive environments with system engineering, information technology, and soft (communication and team) skills in addition to traditional engineering fundamentals [2,3]. Such skills are particularly relevant for Industrial Engineers who often serve as a facilitator of technical and business interactions[4,5].

A number of efforts to increase these skills are being undertaken, the most common being the capstone senior design projects. Curriculum designers are increasingly more aware of developing courses that combine skills from several prior courses to practice such skills. Especially innovative approaches introduce students to systems thinking early and continuously through their program, stressing both engineering and business issues[6]. Programs that have sought to emphasize this approach have ranged from small-scale graduate programs[7]; to departmental[8]; to large-scale multi-institutional efforts[9]. Successful programs supplement traditional engineering science with practical experience in solving real problems, developing the systems, IT and business skills.

2.2 Interdisciplinary Efforts

Increasingly, such experiential learning involves working with multiple disciplines[10]. Many universities, encouraged and supported by industry, now offer capstone senior design projects performed by teams composed of varying engineering disciplines. More recently, the teams for such projects are being expanded to include business disciplines, IT disciplines, and science disciplines. Industry and Business advisory bodies regularly recommend such arrangements because they introduce students to the more comprehensive business enterprise and more closely approach realistic practice.

2.3 Authentic Assessment

Introduction of such interdisciplinary practices not only better prepares students for practice, but also affords educators the opportunity to perform more authentic assessment. The notion of

"Authentic Assessment" or "Performance Assessment" was developed as a response to the criticism of traditional assessment methods such as standardized tests in the context of K-12 education[11,12]. According to Hart [13], "performance assessments are designed to test what we care about the most – the ability of students to use their knowledge and skills in a variety of realistic situations and contexts." As the popularity and use of project oriented classes emphasizing hands-on education continues to grow, educators are faced with the challenge of evaluating student performance in this non-traditional setting. Amos[14] discusses and provides examples of proven authentic assessment techniques, including rubrics and portfolios to validate the satisfaction of industry desired competencies. Some engineering programs (for example, West Point's systems engineering program[15]) utilize their capstone design course to assess the ability of their students in professional practice by engaging the industry clients in the process. As example of authentic assessment is the Membership by Assessment of Performance (MAP) as a new route to membership of the Royal College of General Practitioners in the United Kingdom. MAP allows experienced General Practitioners (GPs), who can show evidence of good quality practice, to become members of the College through an assessment of their performance and a demonstration of the quality of medical care rather than by sitting for the MRCGP examination[16]. Leaders in the US medical education system have advocated the use of performance-based assessment of clerkships (medical students in clinical rotations) as a credible approach for summative as well as formative evaluations[17].

3. Interdisciplinary Virtual Teams

This section contains a description of the Interdisciplinary Virtual Teams model used for this product realization project involving interdisciplinary student teams from two classes, a Computer-Aided Design and Manufacture in the Department of Industrial and Systems Engineering and International Management course in the Department of Business Administration. The Computer-Aided Design and Manufacture is a required course for Industrial and Systems Engineering (IE) Students and was offered in a single section with 26 students enrolled during Fall semester 2002. The International Management course is also a required course for business management majors and was also offered in a single section with 31 students enrolled during the Fall 2002 semester. These Interdisciplinary Virtual Teams were tasked to design, develop, manufacture, and market a unique product globally. A process model developed and applied for implementing this Interdisciplinary[18] Virtual Teams (IVT)[19,20] as well as a step-by-step process guide starting from team formation through completion and presentation of the project to the customer is presented.

The Interdisciplinary project sought to serve as a foundation for students understanding the global market. It was designed as a comprehensive, interdisciplinary, collaborative and challenging exercise allowing students to develop and retain knowledge about global competitiveness. The project was designed to follow the flow of activities within companies that leads to the creation and global distribution of new products. It is designed to cover the following areas: needs identification, innovation, design and manufacture of new products, cost analysis, marketing and distribution. The project's academic objective was to integrate practical interdisciplinary theory with the advantages afforded by virtual teams for learning. General objectives of the project were to:

- Enhance students awareness of a dynamic global market
- Enhance interdisciplinary learning experience (engineering students and business students)
- Enhance multicultural experiences
- Enhance students skills through interactive learning
- Exploit the advantages that are possible through the virtual workspace

The project was structured as semester-long exercise. Project teams consisted of approximately 8 students (typically 4-5 from the business division and 3-4 from the engineering division). The professors involved in the applicable courses as well as the project manager, a graduate student, comprised the Executive Board. Each team reported to and was evaluated by the Executive Board on an ongoing basis at each phase of the project. The model design includes a 7-phase team process, phased progress reports, team meeting presentations and agendas, and team documents such as a Code of Cooperation. A virtual workspace was set up, allowing administration and communication of IVT processes. Each phase of the project was a measurable milestone for the project and follows the flow of activities for the duration of the project as shown in Figure 1.

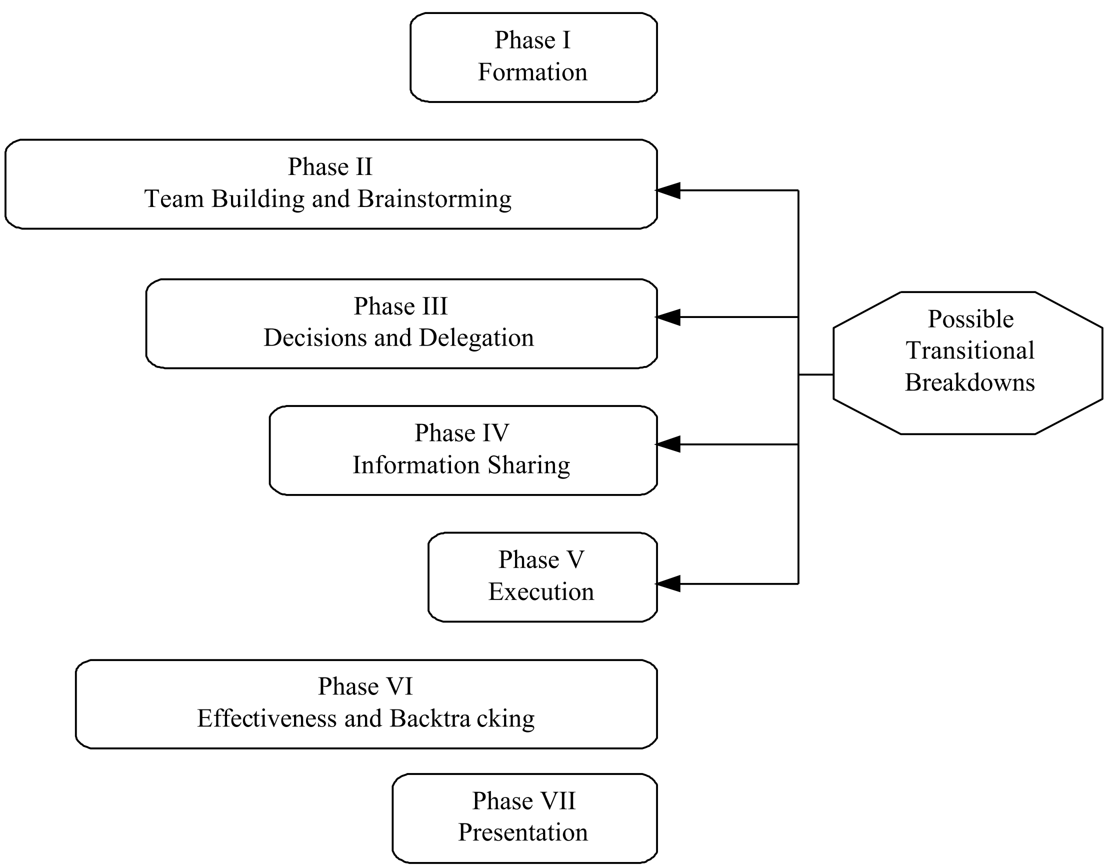

Figure 1: Phase Model with Possible Transitional Breakdowns

At the conclusion of each phase the following deliverables were expected:

- a typed report, (final version to be 15-20 pages with appendices as needed);
- a copy of all Power Point presentation materials for each member of the Executive Board;
- a 15-25 minute oral presentation to the Board; and
- a 5-10 minute discussion period during which the team responds to questions from the Executive Board.

3.1 Project Team Process

The formation phase is when the team selection process took place. The purpose of this phase was to define the project, form the teams, and exchange team member information. Once the classes were selected the project manager, in this case the graduate teaching assistant, gave a presentation on the team format to each class. The next step was to select the team members. The professors of the two classes coordinated team formations for their classes (the divisions) and division leaders were selected. After the divisions are formed within the class, the divisions were then paired up with the other class to make up a "corporate" entity. After the team is formed, all relevant information about each team member was compiled into one list by the project manager, and distributed to the team. Information that was included is team member name, email address, phone number, division, and skills and specialties. This is also when the project was completely defined to all team members. The formation phase took about one week and was considered complete when the team formation process has taken place and the progress report submitted. Each subsequent phase was completed as prescribed in Figure 1. We observed that each class approached each of the phases with a different level of priority. Although the deadlines were established for completion of each phase of the project, we noticed that the first two deadlines appeared to be a surprise to the business divisions of most of the teams. This was despite the fact that regular information and updates on the project was posted on the course websites, as well as the project's virtual workspace on *eProjects.com* which was equally available to both divisions. This process improved by the third phase of the project.

3.2 Lessons Learned

There were many lessons learned from the IVT product realization project. The benefits to student participants were tremendous. Since the students were required to interact with their counterparts from a different discipline at a location separated by a 20 minute walk on the same campus, many were compelled to visit the other part of the campus for the first time, and actually engage in intellectual exchanges that crossed their disciplines for the first time. Students were able to appreciate the different points of view offered to accomplish their projects from the Business Division and the Engineering Division perspectives.

One of the biggest challenges were those of getting the teams to think of themselves as unified teams rather than the Business Division and Engineering Division. It was very common to listen to a given class blame the other division for missing elements in some phase of the project. The professors had the responsibility of reminding the teams continually that the project was to be completed as a team, and that the benefits of excelling as well as the consequences of not accomplishing any step would reflect on the entire team, rather than the division that is allegedly not performing.

The next problem was that of scheduling. Since each class met at a different time, it was necessary to schedule special sessions, with associated hurdles to get both classes together as needed throughout the project. Also, scheduling of the initial meetings of each unified team with the project manager was a very daunting task. The need to coordinate the times for about eight members of a team to designated time slots was painfully slow.

A key lesson learned in this process was that just because the virtual workspace is set up and would facilitate required information exchange, does not mean that the teams would use them. We found out that those teams that complained the most about non-participation by the other division were those who had very limited use of or, in some cases, no use of the virtual workspace for the associated period. We had to document usage statistics and confront non users periodically to encourage them to use the virtual workspace. It was evident that the teams that were actively using this facility were making more progress and consistently exhibited superior performance at each phase of the project, and this remained true when we compared the final grades in the course with the virtual space usage statistics.

Key success factors include an exciting project, planning that enables an early start in the semester, proactive scheduling of the classes for convenient meeting times, and on-going orientation on the utility of the virtual workspace.

Despite the problems encountered, the students and faculty and project manager viewed the IVT product realization project as a success. The students consistently indicated that they thought that the project workload was too heavy. We are planning to implement a similar project in the Spring 2003 semester, taking into account the lessons from the first offering, and are looking forward to another exciting collaborative effort. This second implementation will use an IE class with both senior level undergraduate and graduate students.

The biggest obstacle presented by the class partnering approach is the significant amount of class time lost to project planning and communication. It is estimated that approximately 20% of the IE class time over the course of the semester focused on the project. At the end of the semester, the IE students completed surveys soliciting the level of achievement of class learning objectives. The results of this survey were lower than past semesters. It is speculated that the class time lost to the project resulted in decreased learning of traditional class content. The benefit of the project may outweigh this loss for senior level, design focused classes. However, class partnering may not be appropriate for more content-heavy classes earlier in the curriculum. A shorter, more focused technique for interdisciplinary teaming is appropriate. The following section describes the ALIVE system and its use for such short term interdisciplinary experiences.

4. ALIVE System Discipline Integration

4.1 ALIVE System Description

The NC A&T State University Department of Industrial and Systems Engineering Virtual Enterprise (VE) is a full scale manufacturing supply chain, integrated using information technology, and producing actual product. Departmental laboratories are organized as business departments within an information system-integrated enterprise. The VE departments, their function, and conceptual structure can be seen in Figure 2 with physical structure in Figure 3.

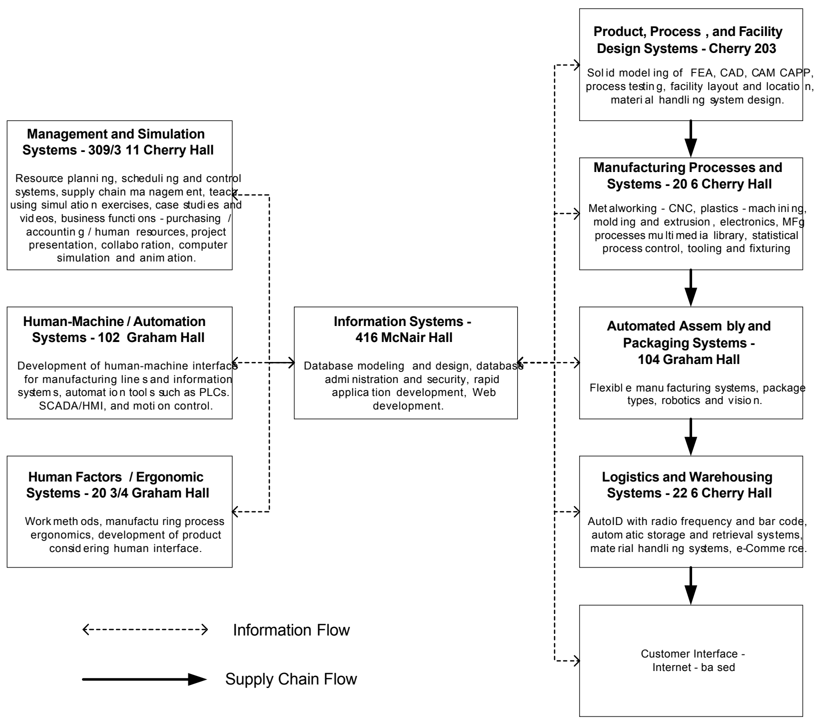

Figure 2: Virtual Enterprise Conceptual Structure

VE systems development requires completion of the following steps undertaken by the Department of Industrial and Systems Engineering with assistance from the National Science Foundation and Procter and Gamble. Steps 1-5 are complete. Step 6 is in progress.

1. *Infrastructure Development* – All departments (laboratories) are equipped with at least two performance computers with connection to a common high speed network.
2. *Process and Equipment* – Processes necessary to design, manufacture, and distribute the desired products are identified. Small scale, flexible manufacturing equipment with computer interface is purchased to perform these processes (in our case, much of our existing equipment is used).

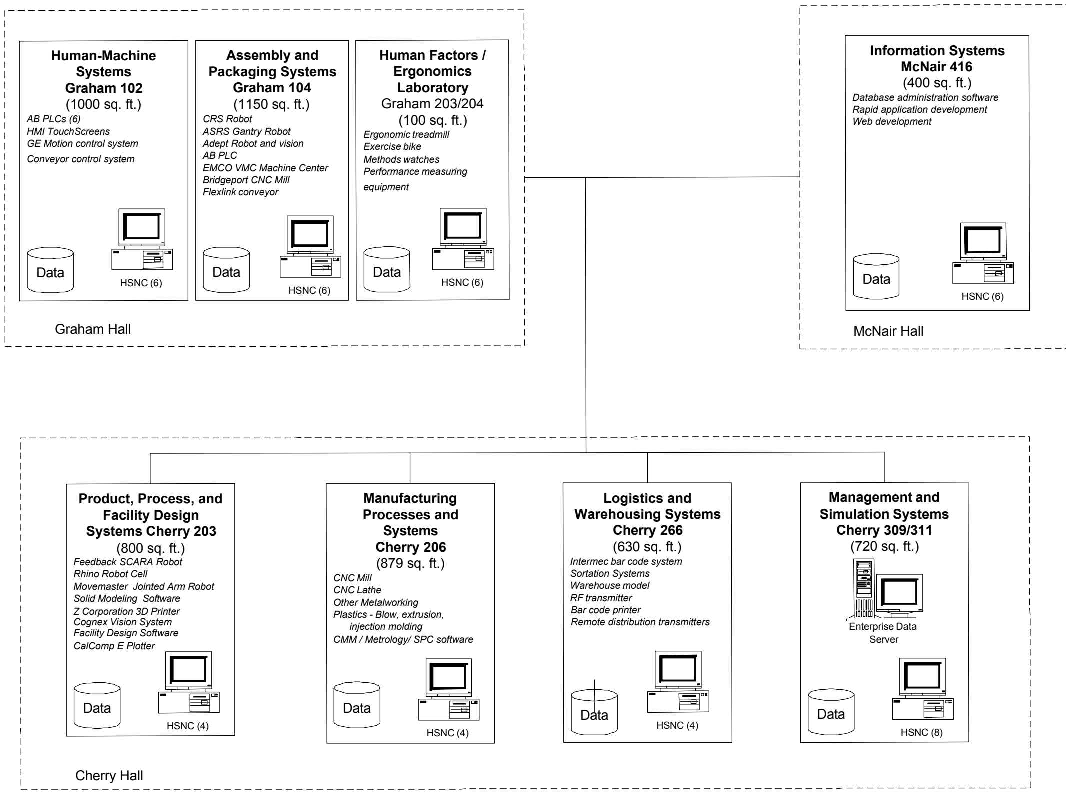

Figure 3: Virtual Enterprise Physical Structure

3. *System Integration* – Purchased equipment is connected to the VE system infrastructure. In our case, all equipment is accessible over an Ethernet network with TCP/IP protocol or through computer connecter to Ethernet network.
4. *Database Design* – The enterprise data model is developed. The data model is comprehensive and complete to be realistic, yet straightforward and simple to promote learning. Our data model contains about 70 entities. The data model has portions associated with supply, product, engineering, manufacturing, distribution, sales and marketing, finance and accounting, human resources, information systems, and other entities. The model is implemented in Microsoft SQL Server.
5. *Server Construction* – The infrastructure is connected to database and Web servers. The database is a client-server relational DBMS. The Web server is used for asynchronous student learning and Web-enabled applications and has a secure interface to the database computer. The Web server has been developed to allow both ASP and JSP functionality.
6. *Program Development* – Simple programs to perform specific departmental functions are written to have the same "look and feel" and demonstrate realistic operation of the department. Programs are based on documented process models using data flow diagram structure.

The VE system is designed with flexible processes to handle multiple products. The initial VE product is a desk clock as shown in the Figure 4 assembly (without timepiece). The desk clock is designed using parametric solid modeling and with a rapid prototyping system in the Product, Process, and Facility (Engineering) Department. Parts are manufactured using injection molding and CNC machining and inspected using a CMM in the Manufacturing Processes and Systems Department. Automated assembly is accomplished in a flexible assembly cell. The cell possesses CNC capability to custom engrave initials and vision-guided robot insertion to insert a timepiece with the correct time (according to the time zone of the customer). The assembly process allows teaching of production postponement and delayed differentiation concepts. A second planned product is a disposable camera. This product facilitates teaching of reverse logistics, product recovery, and remanufacturing.

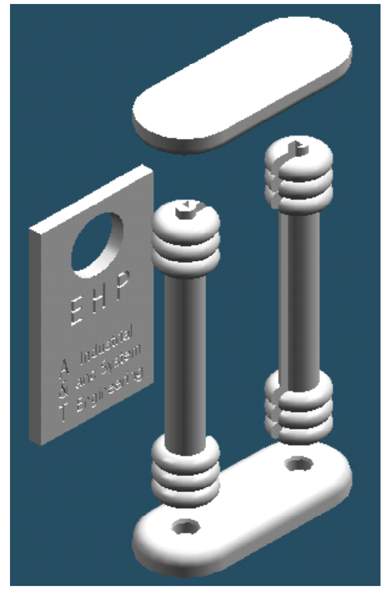

Figure 4: VE Module Clock

Industrial Engineering curriculum integration of the VE is achieved through the ALIVE (Active Learning In the Virtual Enterprise) System. ALIVE is a set of web-based "learning modules" based on the VE. The ALIVE system provides the equivalent of many short intern experiences in different parts of the same small company. It provides a practical and consistent means of developing systems engineering, information technology, and business skills in engineering students. The pedagogical design reaches a variety of learning styles.

Each student learning interaction with the virtual enterprise is termed a learning module. Each course in the Industrial Engineering curriculum would have at least one associated learning module. As a result, the student learns the connections between different classes. Learning modules are performed in teams and typically will consume one week of class time. A learning module requires successful completion of the following steps:

1. Learning objectives – The module starts with a listing of module learning objectives, the basis for student evaluation. The objectives are written using Bloom's Taxonomy to encourage higher leveling thinking. The learning objectives also contain an emphasis on developing problem solving skills in students.
2. Functional training – The next step is to have the student team perform the laboratory exercise focusing on the related functional area. This step is where most laboratory experiences begin and end, with the student left to make all inductive conclusions.
3. Data / process model – The student team will review and analyze the data and process models associated with integrating. The student will learn how to use the virtual system interface. The Web interface allows the student to navigate through the data model and see entity and attribute definitions and types. The process model interface allows decomposition to the code level. (Students will learn how to understand data and process models early in the curriculum.)
4. Economic / value issues – The business issues involved in this function are described with

student teams producing a tradeoff analysis.

5. Other design issues – The student team is introduced to additional systems issues including (where appropriate) social, safety, ergonomic, global, political, and regulatory concerns.
6. Individual evaluation – Each student is evaluated to ensure learning in steps 2 and 3 above. This evaluation is done by a test of skills learned in step 2 and the ability to write appropriate database queries for step 3.
7. Case study – Finally the team demonstrates the ability to synthesize all information learned from steps 2-5 by performing a case study. In the case study, each team member will take on a different role (production manager, engineer, accountant) to assist in collaborative learning. The case study encourages problem solving and higher level thinking skills. Authentic assessment is performed by having two faculty and two industrial personnel evaluate the team performance with a standardized rubric.

Instruction regarding the learning modules is implemented in Web-based format to enhance portability and enable asynchronous learning.

4.2 ALIVE Discipline Integration

A key contribution of the ALIVE system is its usefulness in technical business classes in addition to engineering courses. This ALIVE project involves modifying learning module content to be inclusive of business school needs, yielding a core set of learning modules for business curriculum. This modification will allow not only business school use, but interdisciplinary use in universities where both business and engineering schools exist. Business programs do not have the physical manufacturing equipment, but often have the computational infrastructure to support ALIVE implementations up to the information system level. For interdisciplinary efforts, the case study step would be performed by teams composed of engineering and business students. The exercise would be performed using a "jigsaw" arrangement where each team participant is assigned a specific functional role. That person may be given additional information relative to their function. Since a learning module consumes at least one class and at most one week, the time commitment from the students is minimal. This short term project introduces students to the challenges of interdisciplinary work without sacrificing class content. As with class partnering, the interaction could be greatly enhanced by cooperative scheduling of related classes by engineering and business departments.

Table 1 lists learning modules that have or will be developed for the ALIVE system. Those modules shown in italics may be done with business classes, those in bold may be done with other engineering disciplines. Table 2 shows the associated business classes at our university.

Table 1: Learning Module List

Module Title	Labs	Classes	Class Title
Application Programming	***416 McNair***	***GEEN 102***	***Computer Programming***
Introduction to Virt. Enterprise	***All***	***INEN 246***	***Manufacturing Processes***
Custom Manufacturing	**206 Cherry**	**INEN 246**	**Manufacturing Processes**
Automatic Performance Tracking	102 Graham	INEN 255	Methods Engineering
Activity vs Standard Cost Decisions	***311 Cherry***	***INEN 260***	Engineering Cost Mgmt
Enterprise Data Modeling	***416 McNair***	***INEN 280***	***Information Technology***
Enterprise Web DB Interface	**416 McNair**	**INEN 280**	**Information Technology**
Team Decision Making Using IT	*311 Cherry*	*INEN 289*	*Engineering and Teams*
Statistical Process and System Control	***206 Cherry***	***INEN 325***	***Quality Control***
Inventory Level Optimization	*226 Graham*	*INEN 330*	*Operations Research I*
Manufacturing Execution	104 Graham	INEN 346	Automation Systems
Process Reengineering/ Improvement	104 Graham	INEN 346	Automation Systems
Production Scheduling & Cont.	*104 Graham*	*INEN 355*	*Production Control*
Dist.Planning and Tracking	*226 Cherry*	*INEN 355*	*Production Control*
Material Handling and Control	203 Cherry	INEN 365	Facilities Design
Enterprise Interface Dvlpmnt	**102 Graham**	**INEN 371**	**Human Factors II**
Virtual Enterprise Simulation	311 Cherry	INEN 415	Simulation
Product Redesign and BOM	203 Cherry	INEN 424	CAD/CAM
Process Planning and Tracking	203 Cherry	INEN 424	CAD/CAM
Virtual Enterprise Business Functions	*311 Cherry*	*INEN 485*	*Systems Integration*
Ergonomic Asmt of Assembly	204 Graham	INEN 372	Human Factors I
Reverse Logistics	*104 Graham*	*INEN 485*	*Systems Integration*

Table 2: Learning Module Business Classes

Module Title	A &T Bus. Class	Business Class Title
Application Programming	BUED 342	Business Prog.
Introduction to Virt. Enterprise	BUAD 482	Production Mgmt
Activity vs Standard Product Cost Decisions	ACCT 444	Cost Accounting
Enterprise Data Modeling	BUAD 440	Business Info Sys
Team Decision Making Using IT	BUAD 426 BUAD 520	Org.Behavior Strategic Mgmt
Statistical Process and System Control	BUAD 482	Production Mgmt
Inventory Level Optimization	BUAD 481	Mgmt Science I
Production Scheduling & Cont.	BUAD 482	Production Mgmt
Dist.Planning and Tracking	TRAN 440	Intro to Logistics
Material Handling and Control	TRAN 670	Materials Mgmt
Virtual Enterprise Business Functions	BUAD 448	Systems Analysis
Reverse Logistics	TRAN 440	Intro to Logistics

4.3 ALIVE System Implementation

In anticipation of dissemination to other programs for both engineering and business, several dimensions of portability are designed using the ALIVE system. The first dimension is based on the intended use of ALIVE, for industrial and systems engineering, for business, for other engineering/computer science, or interdisciplinary use. The second dimension involves the level of implementation at a remote site. Options from least to most extensive are:

Web client – Remote institutions use our web site for its students. Web site data would be available to instructors. Lab activities are viewable through streaming video.

Web server – Remote local sets up web and database server with ALIVE system information. This system allows a higher level of customization and permits course instructors to customize the learning module content. An instructor interface is provided.

Information system implementation – Remote location sets up the complete ALIVE system database and applications. The database connection is done ODBC to allow implementation in any RDBMS. Applications are available as VisualBasic or web-enabled applications. This allows the user institution to do all things but make the product.

Complete Implementation – User institution purchases all needed equipment to make the product. Portability is assured when equipment matches that at NC A&T. For differences in equipment, small changes in application programming may be included. These are simple for institutions which would choose this level. Assembly may be done manually if necessary.

The portability of the system is enhanced because it is data-driven. All the content on the web pages is stored in an already developed normalized database (about 30 entity types). This database allows hierarchical and natural browsing through the data and process models and application program. The data-driven nature of the system also allows interface improvements and customization to be done rapidly.

5. Conclusions

This paper contains descriptions of two approaches that allow engineering and business students to work together on practical problems earlier in their academic careers. Such arrangements provide the students a more realistic problem environment, and often motivate the student to higher levels of classroom performance. Additionally, such arrangements can provide educators with more authentic assessment of students and educational programs. The first of the described methods, class partnering, has been implemented with best practices given. The second method, the ALIVE system, is being tested. Each method is based on effective pedagogy including teamwork and cooperative learning, interdisciplinary nature of problems, active participation in learning, open-ended projects that allow communication among students, computers treated as a means and not an end, and knowledge content and its application being interrelated.

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