A Virtual University Approach to Combining On-Campus and Distance Learning with E-Commerce Paradigms

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Abstract

The rapid growth of e-commerce technology and the movement toward expanded outsourcing of product development create significant advantages for research and the education of engineers. This paper outlines some of the facets of the present distributed concurrent/collaborative engineering environment and illustrates some of the research and education issues that must be addressed to cope with this future. It also describes several approaches taken to facilitate collaborative engineering education among different university settings integrated by e-commerce technology.

Keywords

Product Lifecycle Management, PLM, STEP, STandard for the Exchange of Product model data, Collaborative Distributed Engineering, Computer Aided Design (CAD), Computer Aided Engineering (CAE), e-commerce, Electronic Commerce, Distance Learning, Virtual Classroom, Internet, Defense Advanced Research Projects Agency (DARPA), TIGER (Team Integrated Electronic Response), Course Management Tool (CMT)

Introduction

In recent years, there has been an explosion of capabilities in e-commerce driven by the rapid expansion of Internet and web technologies. The result has been a trillion dollar a year business conducted via e-commerce processes. At the same time, engineering companies have been outsourcing extensive portions of the work on major products such as automobiles, aircraft, ships and electronics to suppliers at remote sites. These two trends of e-commerce growth and distributed development greatly complement each other but place significant challenges on engineering research and on the education of future engineers. To date, most major products are developed by teams distributed over large geographic areas and suppliers are assuming a growing proportion of the development effort and decision-making. Major companies are looking more carefully at the supply chain management approach to effectively develop quality products at reduced cost and time. The tools that facilitate rapid seamless integration of distributed engineering activities are varied and not well developed. Furthermore, many of these tools are not tailored to support engineering functions and processes

With rapid advances in manufacturing processes, computational resources, and information technology, it is crucial that employees be trained in the latest trends. Increasingly it is difficult for a corporation to send employees off for extended periods of training and Universities are striving to fulfill this need by providing resources via Distance Learning (DL) initiatives. Pre-Internet, the most common method used in Distance Learning involved transferring lecture materials via the postal service. These materials took the form of printed documents, video and audio media. Today, this system is being augmented and in some cases replaced by streaming video and audio courses via the Internet. Lecture materials can be emailed directly to a student or retrieved manually from a static website 24 hours a day. Secure Internet sites provide an opportunity to administer exams and students can interact with instructors to ask questions via email. At Georgia Tech, a student can complete the entire application process, get accepted to and complete selected degree programs without ever setting foot on the Atlanta campus!

This paper discusses the current e-commerce trends in linking distributed teams and describes some experiences by the authors and others in demonstration projects that help to illustrate issues. It also describes experiences in extending distributed engineering design and distance learning. Finally, the paper identifies several areas where research is needed as well as how engineering education should be extended to meet the needs of a future engineering development in an e-commerce supported distributed development environment.

Perspective on Electronic Commerce

Electronic Commerce and its associated strategies, tools and technologies represent a fundamental change in the manner in how we conduct business in the 21st century global markets. Information on demand via the Internet provides the opportunity for synergistic integration and amalgamation in the flow of goods and information. It is reshaping the fundamental processes and infrastructure governing the efficient and effectiveness of such strategies as e-business, supply chain management, collaborative/distributed engineering and other e-strategies. The traditional paradigm of mass production and economies of scale is being replaced by outsourcing, time-based competition, economies of scope, and mass customization or one-to-one marketing such as business-to-consumer (B2C) and business-to-business (B2B).

In the new millennium, enterprise operations will become more competitive for meeting the demands of delivering customer specified products and services with high quality, fast speed and low cost. Companies distributed by space, function, capability and ownership join together for delivering products and solutions to service the global marketplace. Teams distributed over large geographic areas will develop most major products and suppliers will assume a growing proportion of the development effort and decision-making. The trends for virtual corporations, distributed and collaborative engineering and e-commerce, and increasing global networking of economies will accelerate. In this rapid changing business environment, it is critical to integrate and synthesize information from various enterprise components for identifying a company’s competitive edge and business opportunity and for efficiently managing corporate resources to gain market share.

With the advent of the Internet and its impact on e-commerce, the influence of this dynamic on the economy in general over the past few years and into the 21st century, and business practice in particular, has been tremendous. Changes are happening extremely fast and the scope is breathtaking!

Internet e-commerce technology tools have forced companies to redefine their business models so as to improve the extended enterprise performance linking e-commerce with distributed development, which is properly called e-business. The focus has been on improving the extended enterprise transactions including intra-organizational, B2B and B2C transactions. This shift in corporate focus has allowed a number of companies to introduce a new *supply chain paradigm* using e-commerce tools as enabling technologies in developing new business models. For instance, the Direct-Business-Model employed by industry such as Dell Computers and Amazon.com, enables customers to order products over the Internet and thus allows companies to sell their products without relying on third party distributors. Similarly, business-to-business e-commerce, which is predicted by Forester Research to skyrocket from $500 Billion in 1999 to $1.3 trillion in 2003, promises convenience and cost reduction. The Internet economy accounted for 33% of US economic growth in 1999 representing 8% of jobs.

We believe that supply chain agility is going to provide businesses with a competitive advantage compared to firms without it in the first decade of the 21st century. We also envision an increase in the emphasis on managing the linkage between global product platform development and global supply chain issues, wherein the customer is involved during development, delivery, usage, and disposal (cradle to grave). The supply chain strategy for firms will comprise a seamless integration of the knowledge chain strategy that involves deployment of virtual processes and resources that is information technology driven and the supply chain strategy, which involves deployment of physical processes and resources. In parallel, the Internet and the emerging e-business models have produced expectations that many supply chain problems will be resolved by virtue of these new technology and business models. E-business strategies were supposed to reduce cost, increase service level, increase flexibility and of course profits sometime in the future. However, the reality has not been as kind to these hopes as many of the new E-businesses have begun to flounder or, at best, not reach their full potential. In many cases the downfall of some of the latest high profile Internet businesses has been attributed to poor business strategy planning.

One of the most profound impacts of e-business technology has been the facilitation of the virtual enterprise. The Internet and e-business technologies have enabled profound changes in how products and services are created and delivered to customers. Many of the "new" decisions faced by firms are fundamentally the same as pre-"e" decisions. For example, improved information processing capabilities can reduce replenishment lead times resulting in a shift of the cost versus service tradeoff curve. While it is clear that e-business capabilities are responsible for the shifting curve, the fundamental decision is still choosing the appropriate point on the curve. This is not to say that e-business has not radically changed many business decisions by enabling new kinds of solutions. It has! One of the most profound impacts of e-business technologies is the facilitation of the "virtual" organization. That is, software and information infrastructure, which permits many, firms to be efficiently and tightly linked.

In summary, to compete successfully in the global market, companies need to re-examine the strength and weakness of their operations and restructure their business objectives to adapt to the changing environment in the trading marketplace. E-commerce, supply chain, distributed engineering and e-business strategies are critical in support of a viable strategic tactical and operational plan. To gain a competitive edge, many companies may need to outsource a part of their operations and integrate their trading partners in supply- and selling-chains to create a virtual enterprise for delivering customer specified products and services with high quality, fast speed and low cost. Facing these demands, product and service innovation and time to market are crucial. In both a traditional company and virtual enterprise operations, it is critical to integrate information from various business components for identifying business opportunities and for efficiently managing a companies resources to gain market share using e-commerce, supply chain management, collaborative/distributed engineering, outsourcing and other critical strategies.

Linking Graduate Research with Industry

The Defense Advanced Research Projects Agency (DARPA)-sponsored a collaborative engineering project denoted TIGER. (Team Integrated Electronic Response) which demonstrates advanced engineering collaboration between primes and suppliers using standards-based design and manufacturing tools. This $1.4M program was carried out from 1995 - 1998 under funding from DARPA BAA 95-23. In the TIGER scenario a large manufacturer provides its suppliers early printed wiring assembly/board (PWA/B) design information in a standard STEP (STandard for the Exchange of Product model data) format (AP210). Suppliers use the TIGER toolset via an Internet-based engineering bureau to supplement this information with their process expertise. Descriptions of their manufacturing capabilities are represented using STEP AP220 (figure 1). They then perform a variety of process-specific design checks, including design-for-manufacturability (DFM) and thermomechanical analyses. As members of the product team, supplier's feedback structured design improvement suggestions via a Negotiation Facility. The TIGER scenario was tested with Boeing and Holaday Circuits as a representative prime and supplier, respectively. Other team members were Arthur D. Little, Atlanta Electronic Commerce Resource Center, Georgia Tech, International TechneGroup Inc., and SCRA (the project management lead)(figure 2).

Experiences indicate TIGER leverages the expertise of suppliers to provide certain design checks that are more precise than those typically done by primes. The Internet-based engineering bureau offers these checks to suppliers on a cost-effective basis ranging from self-service (for highly automated product-data driven routine analyses) to full-service (for challenging new analyses). This paradigm provides suppliers advanced capabilities without requiring expensive in-house tools and expertise.

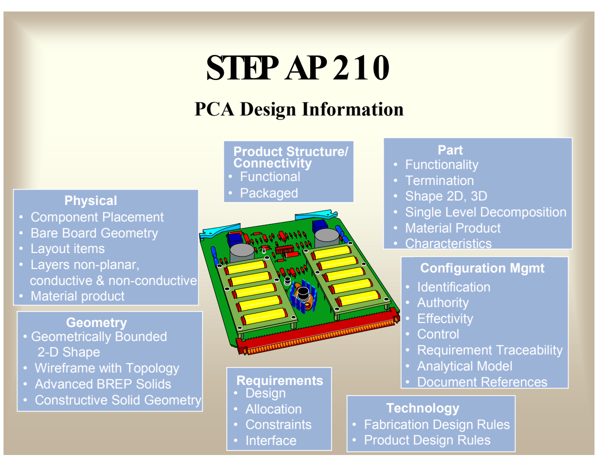

Figure 1

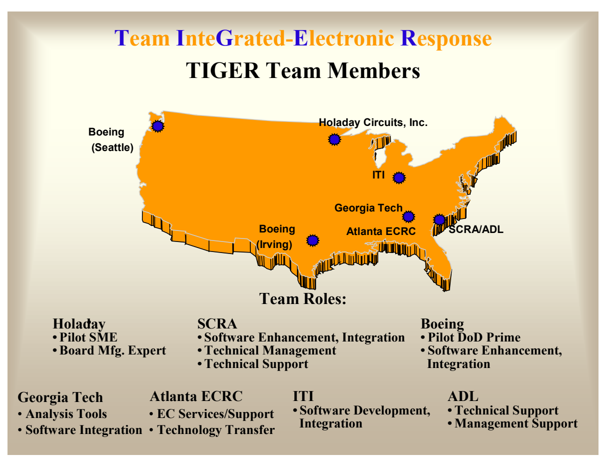

Figure 2

Other accomplishments include the world's first usage of the STEP draft standard for PWA/Bs (AP210 DIS) to drive DFM and finite element analyses - all using live data that originates in the Mentor Graphics circuit board layout tool. Overall, the advantage of TIGER techniques is the effective inclusion of suppliers in the product team, resulting in cost-saving design improvements and reductions in design iterations from days to hours.

Some observations from the study were:
(1) That the supplier was often able to participate in the total design if given the opportunity,
(2) That the prime had downloaded to the SME key decisions that could affect the reliability of the total system,
(3) That suppliers would like to do analyses of their components if give the tools and access to system design definition.
(4) Students get real world experience interacting with their peers in industry.

Web-enhanced Distance Learning Scenario

In the Fall of 2001 there were 55 on-campus (Atlanta) students, 33 in Metz at Georgia Tech's Lorraine (GT-L) Campus in France (figure 3) and 12 typical DL students across the country enrolled in ME6758 (Numerical Methods in Engineering). ME6758 is a graduate level course in which students learn numerical methods appropriate for solving engineering problems on modern computers. Core instruction is on the assets and liabilities of algorithms and how they can be implemented on computers. Grading is based on homework required for virtually all lectures plus a mid-term and final. The issue of logistics was complicated since it was decided to include the Metz students in the second week of class and that resulted in 100 students with a variety of needs. Furthermore, we needed to establish new procedures to accommodate the Metz students and consider them as a single class completing the course on the semester schedule.

Three approaches were used simultaneously for the three sets of on-campus, regular DL and Metz DL students. The first two were typical of the past in that lectures were video taped (digitally), transmitted via the internet and used PowerPoint presentations, augmented by a smart board classroom screen. The smart board is at best only fair for dealing with annotated PowerPoint slides. Copies of all PowerPoint material were available electronically to all students ahead of the lectures but certainly were not error proof. On-campus students turned in the homework in class and the DL students faxed homework and exams to the DL office which in turn were transferred to the ME department, graded and returned. Exams for DL are typically about 1 to 2 weeks later than on-campus. They take their finals after Christmas in accordance with the DL regular schedule (the on-campus semester completes a week before Christmas).

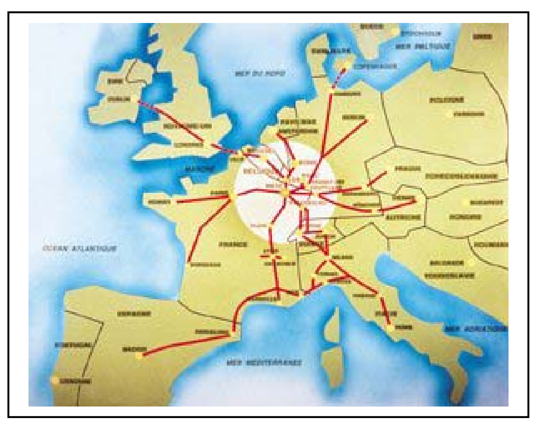

Figure 3

In an effort to treat the Metz students as a virtual on-campus class, but we and the GT-L office staff decided the normal procedure of faxing 25 homework sets to 33 students was unreasonable. After some false starts we settled on the following for the Metz students:

Lectures: The students primarily obtained the lectures as a GT-L video presentation to the total class on a regular schedule using the material produced on-campus about a week earlier. A student contact at GT-L was selected who acted as the intermediary to the numerous operational and scheduling questions asked during the semester. The TA also interacted with a lot of students via e-mail. There were only a few in-class questions on-campus probably due to the size of the class and the fact that the students could visit us off line during office hours.

Pre-Lecture: The 25 PowerPoint draft lecture modules previously used had to be updated and installed on Web-CT prior to each class. We also simultaneously loaded them on another static website as a backup approach which turned out to be useful. Students in the class downloaded them to have a copy before each lecture. They made the annotations and modifications on the material based on what was said in the video. WebCT is a Course Management Tool (CMT) that enables instructors to create and manage web-based learning activities and course materials.

Homework: All homework was manually scanned in Metz by GT-L staff and placed on the website. The TA graded them electronically and provided comments and solutions on the web.

Mid-Term: This was given to the Metz students as a whole on a scheduled date and the results express mailed to the DL office. After grading, the exams were returned and the solution posted on Web-CT.

Final: The final exam on-campus and at Metz was given on almost the same day and the Metz exams were faxed to DL office and hand delivered for grading. Grades for Metz students were posted on time with the on-campus grades.

Observations and Summary

In summary, we completed the on-campus and GT-L course within the semester schedule with quick turnarounds and minor accelerations of work. There were, however, significant logistic issues in dealing with the Metz students as a class. The ME team had to coordinate with the DL office, video operator, Web-CT manager, GT-L coordinators, GT-L student representatives as well as specific students. There were several errors in data files exchanges as well as disconnects among those involved that had to be personally resolved. Sometimes the expected PowerPoint file was not available at the time of the campus lecture. These and other issues were a result of the large class size, logistical problems, numerous channels for information (or misinformation) and small staff to handle the volume of paperwork generated. In the end, the GT-L expectations to operate as a virtual class appear to be greater than with regular DL students and difficult to satisfy without a lot of effort.

We believe this multiple audience scenario is a viable educational strategy, but the level of effort required from the instructor is significantly larger than normal and careful planning is essential. The quality of the course can be lower with the combination of the three groups of large on-campus class together with GT-L and DL students unless an effective strategy is developed. Presentation material that is used must be almost prepackaged textbook quality to meet student expectations (i.e. final form, no typos, highly organized, carefully preplanned homework and lecture packages, etc.). On-campus students are often intimidated by the large class size and videotaping, thus the usual faculty/student interactions are significantly reduced. In the future, it may be more user friendly to not use the PowerPoint material but just use white board video taping which will require the students to be more involved in the class by taking notes for the lecture and the instruction will be more personal. It may also be that the prepared PowerPoint and smart board technology could be a liability not an asset and this strategy may need to be modified. Nevertheless, all students performed on par and we noted no difference between the on-campus and Metz students. We believe the approach is a viable one for e-based education.

Using Product Lifecycle Management (PLM) on-campus

The boom in Internet technologies has forced today's businesses to reevaluate their ability to deliver the right solutions for the right problems in the right timeframe to take advantage of the right market opportunities. How does a company succeed in a global environment with dispersed workers and diverse application systems? How does a company remain competitive: continue building innovative products while reducing cycle times, streamlining manufacturing and cutting production costs? A Product Lifecycle Manager {PLM} is a set of e-business solutions that facilitate collaboration between the people who plan and design products, and the people who build, sell and use them. Using the collaborative power of the Internet, a PLM lets an organization graphically define, share and manage product, process and resource information throughout the whole product lifecycle across the extended enterprise in a real-time workspace. A PLM allows multi-disciplinary business components to collaborate on the planning, development and support of products and rapidly implement proven, results-oriented, and scalable solutions by sharing engineering data throughout the extended enterprise to realize both immediate and long-term operational efficiencies within the product lifecycle. If a PLM can help global manufacturers bring new products to market faster, with improved quality and at less cost we think that it can also improve the workflow in an academic environment.

ME4041 (Interactive Computer Graphics and Computer-Aided Design) is targeted at junior and senior level students of the George Woodruff School of Mechanical Engineering. The objective of this course is to provide hands-on exposure to Computer Aided design (CAD) and Engineering (CAE) analysis techniques in addition to theoretical formulations. Three hours of lectures every week introduce them to the principles of geometric modeling and the finite element method. Two hours of weekly laboratory give them practical applications using the I-DEAS Master Series suite of CAD/CAE/PLM tools by EDS-PLM Solutions (formerly Structural Dynamics Research Corporation) of Milford, Ohio. The students demonstrate their learning with a group design project involving CAD and CAE applications in thermal and mechanical design.

We implemented a PLM in ME4041 to facilitate collaboration between students and to impose a measure of security for product data. In the fall of 2000, two students modeled the internal components of a hand held circular saw (see figure 4). Only these students involved with the project had access to the model data managed by the PLM. As student 2 modeled the outer cover, student 1 could reference the outer cover to design the housing but was prevented from altering the model by the PLM. As student 2 made changes to the outer cover, the PLM alerted student 1 by email that changes were being made that could affect the housing. Student 1 could also begin the assembly of the internal mechanism using referenced parts. Because all data was administered by the PLM, students 1 and 2 could work at different schedules from individual private accounts without the need to meet face-to-face.

A true distributed engineering project was begun in the spring of 2001 when students at Kettering University in Michigan collaborated with students at Georgia Tech via a web-enabled PLM to build components and assemble a power screwdriver (see figure 5).

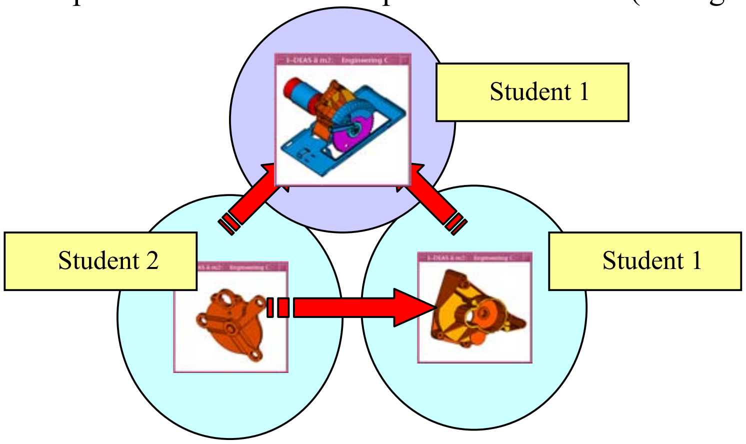

Figure 4

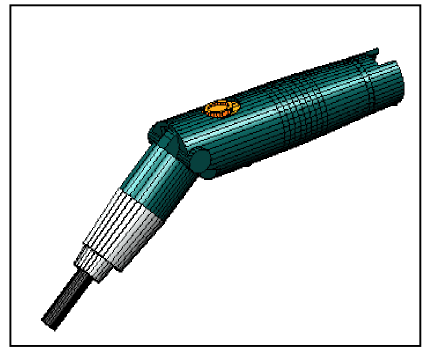

Figure 5

PLM-enhanced Distance Learning

The fundamental idea for utilizing a PLM in an academic setting is that a course can be compared to the lifecycle of a commercial product. A course has a definite start and end date: a lifecycle. Through out its lifecycle, documents are exchanged and deliverables (assignments, quizzes and tests) are due at definite times. The final product is a culmination of all the deliverables as a final grade (see figure 6). Both ME4041 and ME6758 have a similar structure with the major difference between them being the CAD/CAE models created in ME4041 which require the appropriate plug-in modules for the PLM to manage the data.

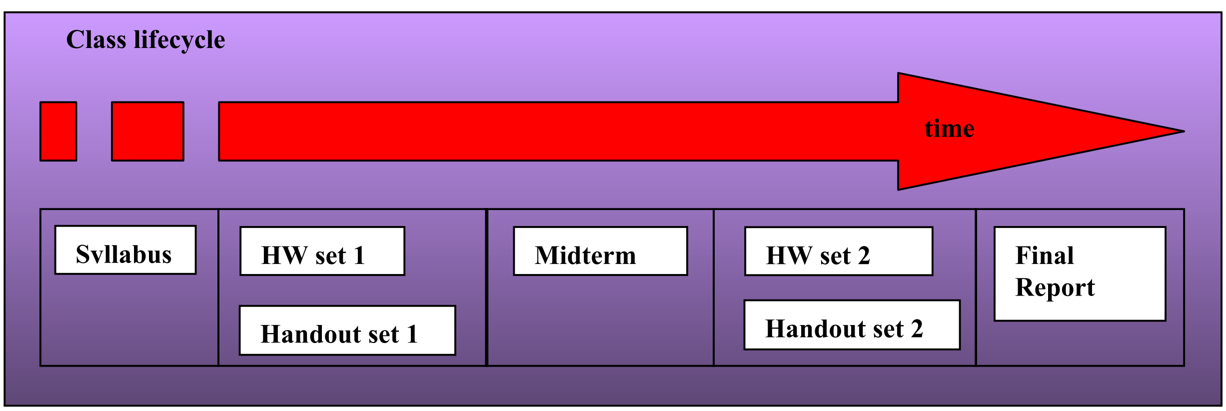

Figure 6

There are many advantages of using a PLM to manage a course:

- Due dates for deliverables can be set and when they have passed, objects can be locked.
- The exact time a document is submitted or exchanges hands can be tracked.
- Documents are exchanged (and tracked) electronically. No danger of getting "lost".

- An instructor can tell exactly when a student accessed the homework/assignment.
- The PLM issues communication via email when an event occurs and keeps a log.

One major change must be made for this to work: all documents must be submitted in a universal electronic format. Our solution: students can do their assignments using any media they want but must convert their submission to Adobe Acrobat Portable Document Format (PDF). Using Adobe Acrobat, the instructor can grade a submission by "red-lining" the document and using the PDF security options to prevent the graded document from being altered.

The lifecycle of a course can be subdivided into mini-lifecycles, each of which can be strictly observed and controlled by the PLM. Illustrated in Figure 7 is the workflow for the distribution of the class syllabus. The instructor prepares the handout (e.g. using Microsoft Word, saves as PDF) and submits it to the PLM. The PLM sends email to all of the students that a document is awaiting their review. The students visit their inbox and retrieve the document (end of Syllabus workflow). Advantage: the instructor can tell who has read the syllabus and when.

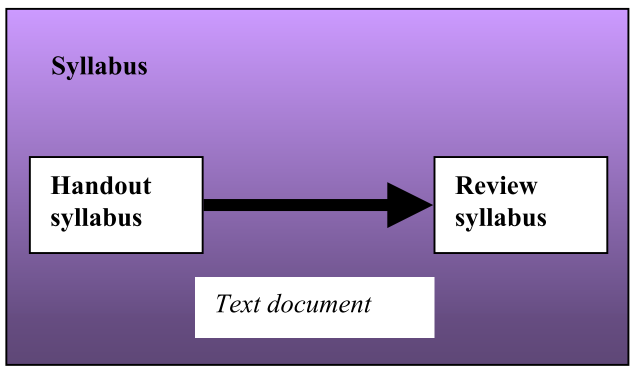

Figure 7

Illustrated in Figure 8 is the workflow for the distribution of an assignment. The instructor prepares the handout that describes what is required for Homework 1 and submits it to the PLM. The PLM sends email to all of the students that a document is awaiting their review. The students visit their inbox and retrieve the document. Each student creates a new text document as per the requirements and saves it to PDF format. The new document is submitted to the PLM and the instructor gets a notification that a document requires attention. The instructor retrieves the document and grades it using Adobe Acrobat. The document is returned to the PLM and email notification is sent to the appropriate student. The student retrieves the document and reviews the grade and grading. The workflow of this activity can be configured to allow the student to revise/make corrections and resubmit the document.

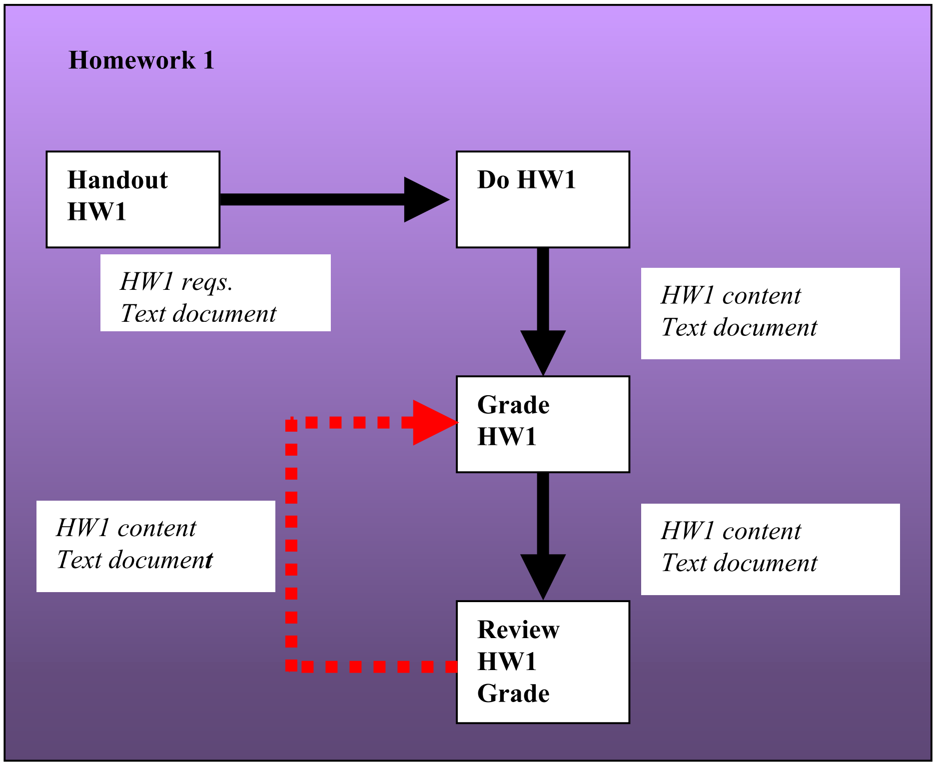

Figure 8

Observations and Summary

Many factors are driving the need to improve the methods used to deliver classroom instruction, among them being the need for Distance Learning and environmental concerns for dwindling natural resources. A typical CMT such as WebCT allows instructors and students to access course materials and participate in learning activities via the Internet. Many CMT's integrate common internet tools (e.g. bulletin board, chat room, whiteboard, email) into one package and add a host of other tools to the virtual classroom: student presentation area, grade book, quizzing tools, interactive calendar, etc. However a PLM has many advantages over a CMT for engineering instruction:

- Workflow management – many engineering curriculums emphasize group activities. Using a PLM, an activity can be divided into multiple tasks and the flow of information between participants can be observed and managed.
- Check-in/check-out ability – A PLM can be configured to handle document security: a particular document can be given read-only access to a group of individuals and modification access to one particular individual.
- Integration with CAD/CAE tools – CAD data retains its assembly structure. Individuals can work on distinct sub-components of an assembly with the PLM handling notifications to the appropriate party when a related component has been modified.
- Time stamp – All data is tracked and dated. Notifications are sent via email to remind participants of impending deadlines. No possibility of lost work, numerous revisions can be archived.

There are still many hurdles to overcome when a PLM is instituted the biggest of them being the administration of the system and the creation of a standard format for data exchange. Every course has different requirements and deliverables and the PLM will have to be configured appropriately. Since every piece of data must be handled electronically, hand written documents must be digitized by scanning into an appropriate format. Last but not least, everyone must conform to using the system as it is structured.

Concluding Remarks

The above examples indicate that future concurrent engineering design and education will be performed between remotely located sites linked electronically with the latest electronic commerce tools. Many forms of information will have to flow freely in real time to reduce the total time to design and produce the products. The process must reduce both the time to carry out contractual actions as well as the time to design such products and must provide a way to preserve

Some issues that must be addressed by future engineering research and education include, but are not limited to, the following:

1. Create strategies for defining and developing products at the early stages of design sufficient to support real time exchange of its evolving definition among all partners in the development
2. Create ways to manage and define subsystems and components of a product such that the subsystems and component can be designed concurrently with free exchange among team members as the product and process evolve
3. Develop methods to better understand how to address critical total system reliability and performance issues that now are often unwittingly off loaded to small suppliers who have little or no appreciation for how their design decisions can impact overall system reliability
4. Create new product data modeling methods and concurrent engineering procedures which are targeted to support concurrent engineering paradigms in a distributed e-commerce based environment
5. Create new and more user friendly ways to better link engineering analysis and design to facilitate rapid design decisions among geographically dispersed team members
6. Advance international information modeling standards such as STEP (Standard for Exchange of Product) data models to include the ability to link a large suite of engineering analysis procedures to product data models and to allow product definition to grow and evolve as the design matures
7. Expand and/or restructure engineering computer aided analysis and design courses in colleges to include significant data modeling and exchange and partnering among design teams that are geographically dispersed
8. Incorporate product data management tools into undergraduate and graduate design courses to provide the types of experiences to be faced in engineering practices in industry
9. Expand engineering undergraduate and graduate programs to encourage more in-depth knowledge of information technology through certificates, minors or other mechanisms

Summary

In summary, the rapid growth of e-commerce technology together with the trends in product development for expanded outsourcing to suppliers place significant challenges on the research and education of engineers. This paper has outlined some of the facets of a future distributed concurrent engineering and distance learning environment and illustrated some of the issues that must be addressed to cope with this future. In particular the paper describes several efforts that need to be initiated in research and education to support a future of distributed concurrent engineering.

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