AC 2011-203: A DISTANCE LEARNING HYBRID PRODUCT LIFECYCLE MANAGEMENT (PLM) CERTIFICATE PROGRAM IN TECHNOLOGY

Nathan W. Hartman, Purdue University, Computer Graphics Technology

Nathan Hartman is an Associate Professor and Assistant Department Head in the Department of Computer Graphics Technology at Purdue University. He is also Co-Director of the Purdue University PLM Center of Excellence. His current applied research interests include the use of constraint-based CAD tools in the design process, the process and methodology for model-based definition and the model-based enterprise, geometry automation, and data interoperability and re-use. He currently teaches or has taught courses in 3D modeling, virtual collaboration, 3D data interoperability, and engineering design graphics standards and documentation. Nathan has taught graduate courses in the foundations of graphics in technology and instrumentation and measurement in research design. He has worked for a variety of companies in using and integrating PLM tools in the engineering design process through the development of custom training applications and materials. Nathan holds a Bachelor of Science in Technical Graphics and a Master of Science in Technology from Purdue University, and a doctorate in Technology Education from North Carolina State University.

Mitchell L Springer, Purdue University, West Lafayette

Dr. Mitchell L. Springer, PMP, SPHR

Dr. Springer is an Associate Professor in Technology Leadership & Innovation and currently serves as the Director of the Purdue University College of Technology, Academic Center for Professional Studies in Technology and Applied Research (ProSTAR) located in West Lafayette, Indiana. He possesses over 30 years of theoretical and industry-based practical experience from four disciplines: Software Engineering, Systems Engineering, Program Management and Human Resources. He sits on many university and community boards and advisory committees. Dr. Springer is internationally recognized, has authored numerous books and articles, and lectured on software development methodologies, management practices and program management. Dr. Springer received his Bachelor of Science in Computer Science from Purdue University, his MBA and Doctorate in Adult and Community Education with a Cognate in Executive Development from Ball State University. He is certified as both a Project Management Professional (PMP) and a Senior Professional in Human Resources (SPHR).

A Distance Learning Product Lifecycle Management (PLM) Certificate Program in Technology

Abstract

The Department of Computer Graphics Technology (CGT) at Purdue University, in conjunction with the Center for Professional Studies in Technology and Applied Research (ProSTAR) and in coordination with The Boeing Company's Learning Training and Development (LTD) team, designed, developed and are incrementally delivering a distance-based Product Lifecycle Management (PLM) Certificate Program. This paper will address the issues and resolutions of the program development process, the highly coordinated and synchronized development process, and the success and process improvement of the delivery of the Certificate in PLM. This work will be presented in the context of adult learning strategies and an online course delivery model. Additionally, this paper will discuss the strategy for the toolset selection, the course delivery architecture, the benefits of the application and methodologies inherent in the virtual application of manufacturing in PLM environments. This Certificate program has been demonstrated successfully in one complete curriculum cycle and is now incorporating process improvement for a successive offering.

Adult Learning Strategies and the Online Delivery Model

Distance education has gone through a number of evolutionary stages since its inception, including online web-based delivery coupled with graphics and audio capability [1,2]. According to Kearsley [3], online instruction includes any form of learning or teaching that takes place via a computer network. This definition fits much of what is available to educators and students today – high-speed networks, visual representations including 3D graphics and motion, and nearly real-time assessment mechanisms – and what is coming in the future. The evolution of computing technology and the desire for learning in the general populace has given rise to increased usage of online media as an instructional delivery mechanism. More people than ever before have access to education and learning content due to this delivery mechanism. The online delivery medium allows people the flexibility to control the following aspects of their learning experience: their learning path, pace, location, time and contingencies of instruction [4].

Current literature suggests that online instruction can be as effective as face to face instruction [5,6], although educators have historically valued face to face instruction. While Russell cites a phenomenon known as “no significant difference,” critics of online learning environments cite a successful outcome that is too dependent on learner motivation, the inability to engage learners in active learning, and the development time and cost associated with creating instructional materials and configuring the online learning environment [7,8,9]. Although Knowles [10] suggested characteristics of adult learning nearly 40 years ago, these factors are relevant today as it relates to distance education, particularly with regard to online learning for the purposes of professional practice:

- A supportive environment in which constructive criticism is not aimed at individuals but instead focused on content and ideas.
- The starting point and focus of a course should be the needs and interest of the adult learning.
- Course plans should include clear course descriptions, learning objectives, resources, and time lines for events.
- General to specific patterns of content presentation work best for adult learners.
- Active participation should be encouraged, such as by the work groups, or study teams[17].

In a study by Wittenborn [11], it was shown that the presentation of product lifecycle management (PLM) and computer-aided design (CAD) concepts was effective in engaging adult learners (who were also working professionals) and delivering content effectively. Totten & Branoff [12] have outlined the use of online instruction for teaching engineering graphics content (a constituent element of PLM) and several critical factors to consider, including interactivity and the difficulty of achieving synchronous educational environments with this topic matter [13].

In an effort to address the challenges outlined in this section, the authors have engaged in the creation of an online professional certificate program in product lifecycle management (PLM) for the aerospace industry. Product lifecycle management is generally defined as a business process that tracks, collects, and disseminates product data (from concept to disposal) through the use of enabling digital technology tools and infrastructure in an effort to make better business decisions and leverage a competitive advantage. As such, many of the same challenges as those listed above have been encountered: the differences between professional and traditional education, the use of online methods to deliver PLM content, the challenges of configuring the online virtual infrastructure, and the logistics of maintaining the curriculum.

Developing the PLM Certificate Program Development – Tools and Process

The beginnings of the Purdue PLM Certificate Program (PLMCP) started in 2006 as an attempt to address knowledge deficiencies within the aerospace industry regarding the deployment and use of PLM enabling technologies. The Boeing Company was in the process of implementing PLM tools and processes and needed education for their workforce that would address the gaps between management's directive to engage in PLM and the practitioner's use of the tools to perform their daily job. After consulting with Boeing's internal training and development organization, a curriculum was put together to address 3D solid modeling, product data and configuration management, and digital manufacturing. Boeing's subject matter experts and training coaches were instrumental in the course sequence and the development of the topical content. While the curriculum does not include any proprietary information, it does mirror processes and technology implementations in the aerospace industry, thus readily enabling learning transfer from the classroom to the job setting. Feedback was gathered from students at the end of each course and incorporated into the next revision of the curriculum.

In June 2007, a cohort of 20 students started the first course. The students were from various backgrounds, including design, manufacturing, purchasing/procurement, quality, and administration. The lecture content was delivered online from Purdue faculty during evening hours on Monday and Wednesday. However, between Course 1 and Course 2 in the program, a number of people dropped out. A number of reasons for this were cited in end of course evaluations, including current work assignments taking priority, change in work scope or assignment, personal reasons, and a lack of continued interest int eh program. Eventually, twelve people finished the entire three-course sequence to earn the PLM certificate. The laboratory element of the courses was delivered onsite at a Boeing training facility using a Boeing instructor. The university faculty member was online at that time to provide assistance and to aid in facilitating the connection between the conceptual topic matter and the laboratory content using PLM tools. The first cohort of students finished their version of the PLMCP in March 2008. However, between the end of the first cohort and the beginning of the second cohort, a number of things happened that caused the fundamental structure of this program to change. Foremost, Boeing decided that they did not want to host an on-site laboratory session, because that limited access to only those people at that specific location. In addition, they wanted employees to be able to access the PLMCP during off-hours, which meant they would not have access to Boeing computing resources. At this juncture, it was determined that an online solution would be necessary. In addition, a change in software tools was required, so the curriculum had to be thoroughly revised to reflect a change in the PLM toolset being used. In September 2009, the second cohort of 22 students started the program. Due to ongoing curriculum and course revisions, the cohort number dropped to twelve students again, which is the anticipated number that will finish the second PLMCP cohort in April 2011.

The infrastructure put in place to support the PLMCP has come in two stages: that which is hosted by Purdue and that which is hosted by a virtual hosting company. The technical details vary widely in some cases. After a few different attempts at creating a hosted solution on campus, the delivery infrastructure evolved to a networked architecture using an HP Gigabit Procurve switch 2900-48G and the Purdue Data Network infrastructure to access the commodity Internet. Originally, the program was using 3 Dell PowerEdge 2900 servers (2 CPU for 8 cores and threads total, 16 GB memory, direct attached storage on each server, up to 8 spinning disks). Currently, the program is using two physical servers powering the production PLMCP instance, with one reserved for curriculum development. The license servers are maintained by the College's central IT group, and the distance delivery mechanism (a Citrix solution) is managed by the university's central IT group. The Citrix server farm was using a Windows Server 2003 platform, but the servers were recently upgraded to Windows Server 2008 R2.

Currently, the PLM tool instance to support the program (e.g., PDM, CAD, digital manufacturing tools) has been upgraded to include much better hardware. This was done in an effort to scale up the program at a future date. It includes one Dell PowerEdge 710 server (2 hyper threading CPUs for 8 cores and 16 processing threads, 32 GB memory, direct attached storage with 16 spinning disks). This level of server allows the program's back-end hardware to support the use of virtual machines (VM) (Hyper-V R2 to host virtual machines; 3 VM's used consuming 16GB of memory, 12GB for Teamcenter and 4GB for supporting VM's), which allows for easier server maintenance and enhanced reliability.

All server OS instances are Windows Server 2003 R2 64 bit , and all client OS instances are Windows XP Professional SP3 Oracle 10G for the database. When Course 2 was developed and deployed, the choice was made to incorporate Boeing-specific software configuration to promote better transfer of learning. Boeing templates, extensions, and code were imported to make our PLM environment look more like their environment. Figure 1 below shows the current PLMCP technical architecture. The point in sharing this information is to illustrate the non-trivial nature of developing and deploying a program such as this. The very fact of delivering PLM education in a *synchronous* fashion requires hardware of this level to be effective.

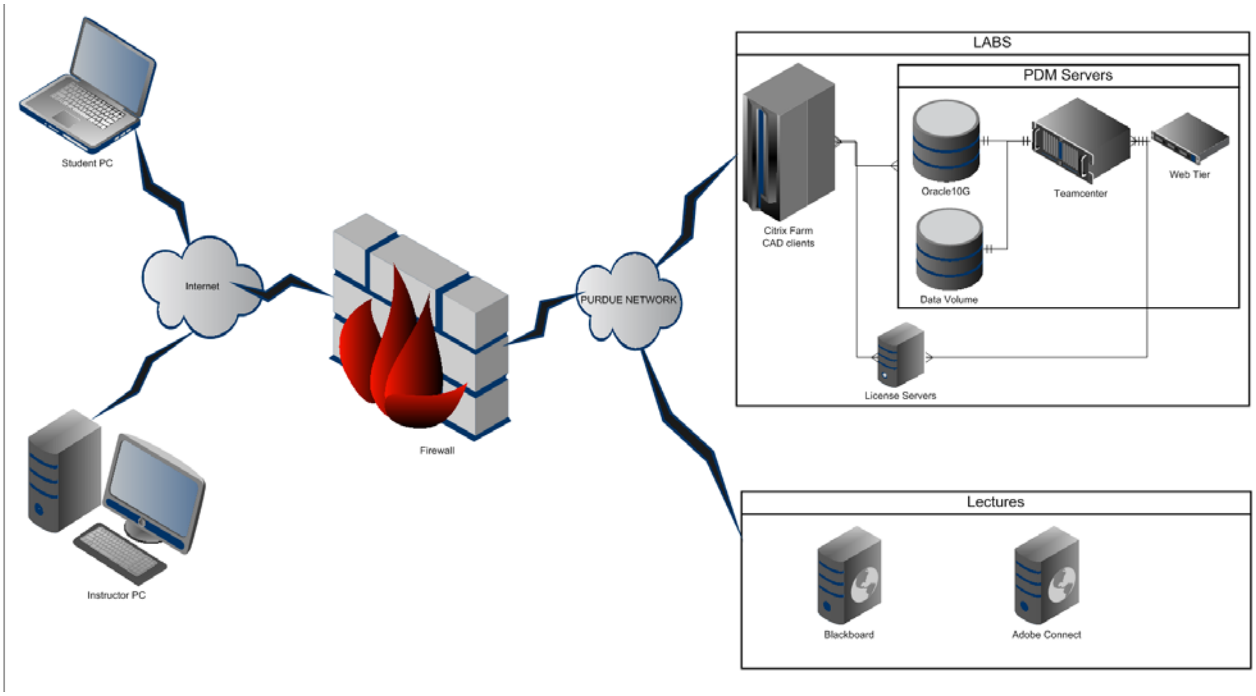

Figure 1: Current PLMCP Delivery Infrastructure

With the interest in the program growing, the aforementioned infrastructure is quickly becoming cumbersome for scalability reasons. As such, the PLMCP is moving in the direction of using a hosted virtual machine solution from a*n external solution provider. The plan includes the migration of our virtual machines to the cloud solution* provided by the virtual hosting company. The PLMCP server and client configurations will be re-created using server templates from the virtual hosting company. A virtual lab of client machines will be created that connect to the server configuration. Both administrators and end users utilize a web browser to access these virtual resources managed by the hosting company. Figure 2 shows the future delivery architecture. The PLMCP software running on virtual infrastructure will query our license servers at Purdue. By investing in the use of a virtually hosted solution, the PLMCP program will be able to be scaled up to serve more students than it is currently capable of serving. The management of such a program will also become easier as it would be able to handle multiple instances of a software installation, allowing the potential to have multiple versions of a PLM technology installed and configured for student use.

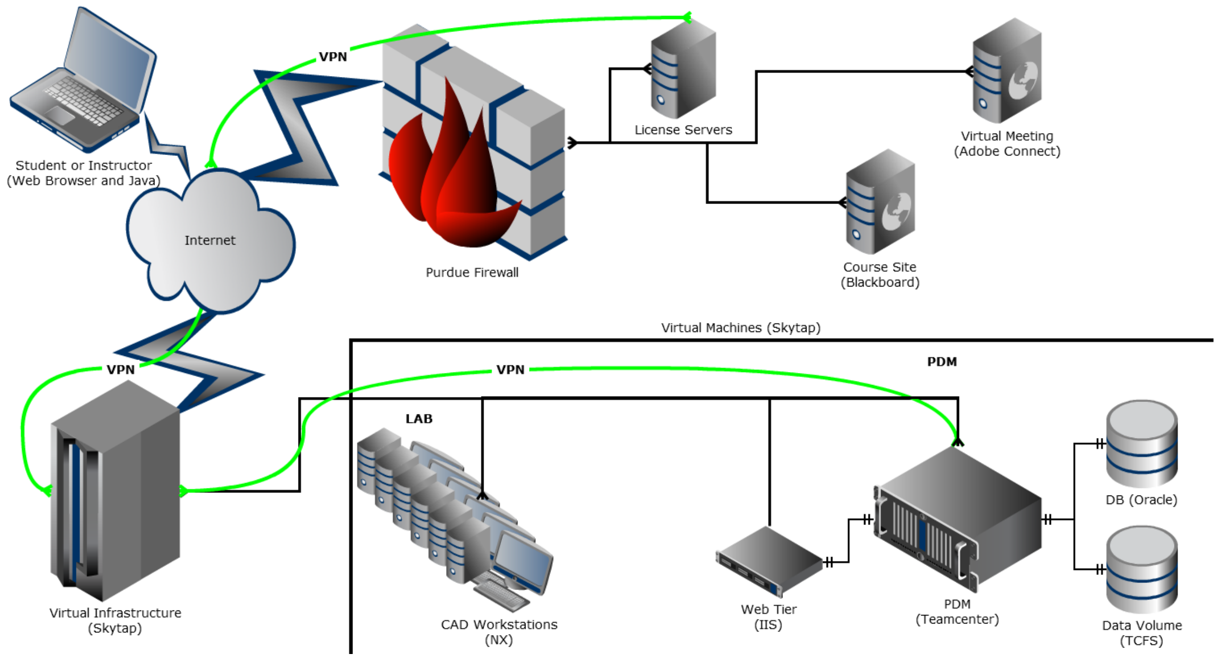

Figure 2: Future PLMCP Architecture using Virtual Host Technology

The PLM Certificate Program Overview

Course 1: Introduction to 3D CAD Design in PLM Environments

The goal of this course is for students to understand the methodologies and application of virtual 3D modeling for use in functioning PLM environments. The course will emphasize PLM as a strategic business initiative and will introduce students to strategic importance of the proper application of 3D model-based definition as a virtual product design tool in a functional PLM environment.

Weekly Topics:

- Introduction to PLM
- Design Intent, Sketching & 3D Solid Modeling
- The Design Process
- Parametric Modeling
- Introduction to Relational Design
- Introduction to Curves & Surfaces
- Surface Modeling
- PLM Strategy as a Vision
- Collaboration & Collaborative Product Commerce

Course 2: The Methodologies and Application of Relational Design in PLM Environments.

The goal of this course is for students to understand the methodologies and application of change management and relational 3D CAD product design within the confines of a Product Data Management (PDM) system in PLM environments. This course will build upon the concepts of the of 3D CAD product design by using a concurrent engineering environment and incorporating relational 3D CAD and PDM databases in the lifecycle of products. The course will emphasize PLM as a strategic business initiative and will introduce students to change management, configuration management and relational design using a combination of the 3D model-based definition and the product configuration management tool.

Weekly Topics:

- Top-down design
- Relational Design
- Program Management
- Change Management
- Product Structure Management
- Configuration Management
- Parts Management
- Customer relationship management
- Action Management
- Interoperability
- Enterprise resource planning
- Introduction to databases
- People, Organization, and Security

Course 3: The Methodologies and Application of Virtual Manufacturing in PLM Environments

The goal of this course is for students to understand the methodologies and application of virtual manufacturing in functional PLM environments. This course will use the product data generated from the relational design course and it will allow students to validate the build phase of a products lifecycle through the use of virtual manufacturing simulation process methodologies and applications. The course will emphasize PLM as a strategic business initiative and will introduce students to virtual manufacturing simulation in a relational design PLM environment using a combination of the 3D model-based definition and the product configuration and virtual manufacturing database.

Weekly Topics:

- Introduction to Digital Manufacturing
- Process Planning I
- Process Planning II

- PPR: E-BOM, M-BOM, R-BOM
- Assembly Planning
- Design for Manufacturability
- Work Instruction Authoring
- Discrete Event Simulation
- Human Task Simulation
- Basic Ergonomic Analysis

Each course meets twice a week in the evening in an effort to reduce the impact on each student's work day. Currently, six different Boeing locations across the U.S. are represented by the students enrolled in the program. And while they all are Boeing employees, the nature of their work is quite unique given the different products they work with. Each class session is facilitated by a Purdue faculty member and a Boeing adjunct instructor/subject matter expert. It is held online using either Adobe Connect or WebEx to enable synchronous communication, common information presentations and to take attendance. A teleconference phone line is used to facilitate communications between all members of the class. Blackboard Vista is used as the course management software to distribute lecture slides, laboratory activity documents and course syllabus. Each class session generally starts with the instructors discussing the weekly topic followed by more open dialogue between the class members. Both Adobe Connect and WebEx allow for an "online chat," which gives students the opportunity to take discussions items into more detailed conversations after the rest of the class moves to the next topic or to carry on related conversations without disturbing the rest of the class. All class sessions are recorded through Adobe Connect and WebEx and a link for the recorded session is placed into Blackboard so students can have an opportunity to review course topics at a later date without losing the context of the discussion.

The Role of the Center for Professional Studies and Applied Research (ProSTAR)

In an effort to address the logistical challenges of managing professional educational programs and maintaining quality while developing and delivering content for the program, the College of Technology at Purdue University created the Center for Professional Studies and Applied Research (ProSTAR).

ProSTAR's organizational model revolves around the primary functions of applied research (a foundational element of the ProSTAR charter and name), graduate programs (including a PhD program), international programs and programs implemented through 100% distance learning. ProSTAR is instrumental in managing enrollment, developing budgets, and interfacing with corporate sponsors, while faculty and staff are focused on curriculum content and the online delivery mechanism.

Applied research focused on the scholarship of professional technical education and actual application of technology to proposed industrial problems or perceptual areas for improvement. It is through the applied research functional area that PLM was orchestrated.

Summary and Next Steps

Throughout the development and delivery of this program, one thing has remained clear – the team working on this project, both from The Boeing Company and Purdue University, was in a position they had not been in before. The challenge of online delivery lines up well with those posed in the literature. The delivery of dynamic, interactive software applications via the commodity Internet, in such a way as to make the only end user requirement as access to a web browser and a DSL-minimum connection, is not a trivial task. Students were briefed on minimum network access requirements, attendance expectations, and assignment expectations. Student attitudes towards online instruction and the level of error-free functionality had to be overcome.

The implementation and integration of back-end systems to serve this teaching and delivery application was full of challenges. Not enough dedicated network bandwidth on the university side, lack of straightforward integration between learning management systems and the PLM toolsets that were being used, security concerns within the Boeing firewall, and archival and maintenance of each cohort's learning environment within the PLM tool were just some of the more prominent technical challenges the team faced when deploying the computing architecture to support this program. One of the other issues we faced was time – for development, deployment, assessment, etc. Many of the elements dealt with in stride during a class done via traditional delivery were taken on in real-time with this program, such as student access of the materials, learning gains by the students, and the importance of student sense of inclusion, and the network capability and capacity to deal with this type of instruction [14,15,16]. In addition, university and departmental administration questioned the value of what was being done (especially in the later stages) given the amount of time being dedicated to the effort and the perception of the impact of the results.

At the time of this writing, the team was preparing to use a third-party virtual hosting company to address the issues of bandwidth and scalability of delivery. The results of that pilot will be used in determining the extent to which this program is marketed to other companies and the time frame by which such scaling could be accomplished. In addition, a period of formative evaluation and revision to the curriculum will take place during the late spring and summer of 2011. A goal is to begin offering this PLM Certificate Program to another cohort of students in early September 2011. Students from Boeing and other companies will be recruited to enroll.

The ability to deliver dynamic, interactive applications and content via the commodity Internet is not a phenomenon that will run its course any time soon. This need will persist, and will be addressed, in various ways into the foreseeable future. The education domain is rich with examples where using graphics, and the tools to author them, can make an impact on student learning. The need for a consistent and well-controlled instructional environment is also well-understood. The elements of this program illustrate a combination of these factors. Also growing is the need to address the educational requirements of the incumbent workforce, those people who have chosen a technical career path who need additional education to remain effective and vibrant in their chosen professional. Universities are in a position to be part of the solution to address these national needs if programs and infrastructure can be put in place to enable this type of education to take place in an effective, cost-efficient manner.

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