Integrating a Product Life-Cycle Management System into a Freshman Level Classroom Environment

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Abstract

This work in progress explores the implementation of a Product Lifecycle Management (PLM) system in an academic scenario that is similar to the way it is used in industry. The goal is to familiarize students with the specific workflows and processes associated with these systems and provide a more contextually relevant environment, so they can be better prepared for their future roles as professionals. For this project, we built a PLM system to administer nearly all aspects of a freshman level CAD course, including weekly course content, assignment submissions, group projects, and grades. In this paper, we emphasize the differences and similarities between a typical company organization structure and a classroom structure and discuss the implications of PLM systems in classroom dynamics, curriculum and grading.

Introduction

This paper builds on the idea that the implementation of a Product Lifecycle Management (PLM) system in an introductory level freshman course can provide students with key competencies to succeed in today's complex design engineering environments. Being exposed to PLM systems early and in the context of entry level modeling courses allows students to become familiar with PLM concepts and how PLM systems are an integral part of modern design processes. Students entering the workforce will have a firm understanding of the various stages and changes a product goes through during its lifecycle and how PLM and CAD are not mutually exclusive, but complementary to each other.

Students in the Department of Computer Graphics Technology at Purdue University become skilled at using standalone Computer Aided Design (CAD) software and receive basic instruction in the concepts of PLM and the Digital Thread. However, they are not sufficiently exposed to CAD in the context of PLM. Consequently, when these students enter the workforce in the form of internships or full-time employment, their limited knowledge and lack of experience with PLM systems are not sufficient to effectively work within the context of one.

The long-term goal of this study is to determine the most effective strategy to expose freshman level students to the concepts of PLM by integrating an industry level PLM system in the course without compromising the primary learning outcomes.

Background

In the modern educational environment, many instructors have embraced web-based Learning Management Systems (LMS) to manage course data. According to Cavus et al. [1], "An LMS is often regarded as the starting point for developing an online course or program by researchers as it provides a means for managing, delivering, and tracking online instruction and student outcomes." Furthermore, an LMS also acts like a bridge between the instructors and learners by providing a common point of contact and direct line of connection [1].

To be an effective system, an LMS must meet several requirements: availability, scalability, usability, interoperability, stability, and security [2]. Availability, as the name suggests, is how available the system is to different users. This encapsulates the ability of the program to serve the needs of many users, including students, instructors, administrative faculty, and technical support. Scalability refers to the ability of the system to be expanded to include more users and possibly more capabilities that are needed for larger implementation. Usability refers to intuitiveness, user friendliness, and ease of use. Interoperability is crucial as it determines how well a system can handle different types of data, including the ability to connect to other programs and services. Stability is how resilient the system is to large user counts and how well it is able to operate while in constant use. Finally, the security of a system is how well it can selectively restrict content to users and safeguard its systems from outside intrusion. Security is particularly relevant in collaborative PDM environments, as stated by Rouibah & Ould-Ali [3]. In addition to these capabilities, Hall [2] suggests that from an operational point of view, an LMS and its components should also be web-deployable to allow users to access the system anywhere there is an internet connection [2], maximizing the potential for collaborative learning [4].

In a study by Klobas and McGill [5], the authors explored the involvement of student and instructor roles as a factor for LMS success using the model proposed by DeLone and McLean [6]. According to this model, six measures can be used to determine information system success: system quality (technical quality of the LMS), information quality (data obtained from the system), service quality (support and services), use, user satisfaction, and net benefits [5, 6]. The last three success measures are particularly relevant as they can be influenced by student and instructor involvement with the LMS [5]. Other methods that have been proposed to determine success include the NASA Task Load Index (TLX), an assessment tool that rates the perceived workload of a task according to six subscales: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort and Frustration [7].

Our study focuses on the deployment of a PLM system as an LMS with the goal of exposing students to PLM practices without sacrificing efficiency, as well as delivering more relevant instruction without negatively impacting student success. Although PLM systems are typically linked to the CAD sector [8], many of their capabilities resonate with the functionalities of an LMS. This places them in a prime position to supplement or even replace existing LMS systems that are not as tailored to CAD instruction. According to Pezeshki et al. [9], "a PLM method can be viewed as a sophisticated tool for analysis and visualization, enabling students to improve their problem-solving and design skills, but more importantly to improve their understanding of the behavior of engineering systems."

Because of the prevalence of free online collaboration services, tools such as Google Drive, Skype or Dropbox have become almost required for students whenever a collaborative project is assigned [8]. However, the use of online tools outside of an LMS often results in poor traceability, project revision control, and file management. Email communication has also been shown ineffective [10]. From an engineering and design standpoint, the understanding of PLM systems is crucial if a student is to operate effectively in industry.

The need to incorporate Product Lifecycle Management in the design and engineering education curriculum was discussed by Fielding et al [11]. Some instructors have introduced Product Data Management (PDM) systems into classes to support student project collaboration. For example, project BLUME introduced the PDM system Windchill (PTC) as a backbone for mechatronic product engineering education in various Austrian universities [12-14]. In this project, the PDM system is described as a tool to facilitate collaboration within large teams in a multi-CAD environment, which is seen as an essential skill for future jobs [12]. However, to the authors' knowledge, no solution has specifically used a PLM system to help administer a design class. In this paper, we describe the design and implementation details of a PLM solution to manage assignments, group projects, and maintain grades. In this context, students quickly experienced that CAD, configuration control, and PDM are not mutually exclusive activities, but must work within the context of a PLM system.

Methodology

The freshman course selected for our study provides an introduction to 3D geometric modeling and the construction techniques used in the creation of constraint-based solid and surface models. Both part modeling and assembly modeling are included, as well as the manipulation of the geometric model. Emphasis is on the use of the design process as a problem-solving method, and the capture of modeling behavior to enable the downstream use of 3D solid and surface modeling databases. The role of the 3D model in the overall product design process and the place of the geometric product definition in the product lifecycle are covered. The implementation of a PLM system in this course is aimed at supplementing this instruction by preparing students to work within the context of PLM and learning that modeling, configuration control, and PDM are not mutually exclusive activities.

The stakeholders of this project include students, professors and advisors in the department that administer the related courses, teaching assistants, information technology experts and the PLM vendor, Aras Corp. All the stakeholders were interviewed to determine an effective design approach and collect important details such as the need for different kinds of workflows, root administrative identity placement, course dynamics, and the various manners of administering a 3D modeling course.

Discussions with students and faculty revealed that standard learning management systems are not appropriate for effectively managing the volume and complexity of CAD data and its related processes, particularly in situations where data need to be shared such as group projects. Furthermore, because of the peculiarities of CAD data and the flow of information throughout the design process and their assignments, there are inherent substantial differences between an LMS and a PLM system which need to be considered when structuring a CAD curriculum.

Questions with IT administrators dealt with the systems side of the project such as CAD software licenses, handling old student identities, technical support availability for potential issues for students and seamless integration of the system with various CAD packages.

The major objectives include:

1. Managing grades and course administration for courses with multiple lab sections
2. Managing assignments delivery and submission
3. Seamless integration with CAD packages (specifically, CATIA V5 and NX)
4. Meeting all FERPA requirements
5. Development and deployment of workflow and lifecycle maps
6. User and group identities and permissions
7. Redeployability of the database and ability to reset the system for new semesters

Implementation

Our system was developed over the Aras Innovator platform [15]. Aras Innovator is an open-source PLM system with a web-based service-oriented architecture that is highly flexible, customizable, scalable and upgradable. Custom workflows and lifecycle maps were developed to control various course processes such as assignments and student submissions. In Aras Innovator, a workflow is a flowchart-like representation of a group of activities. These activities control how an item is assigned and what tasks need to be accomplished by the assignee(s) before it progresses to the next stage. Workflows allow group voting (so that advancement is reliant on team communication and agreement), escalation and notifications (which can be sent to users at different stages of the workflow). Lifecycles represent the different states an item's instance exists. The updating of a lifecycle state is controlled by a workflow.

Additionally, our system uses XPLM [16], a software connector between the CAD system and our PLM system that provides students with a seamless interface to transfer CAD models to the PLM system directly from the CAD application. A file stored within the PLM system maintains full traceability and can be accessed from the CAD system without opening the PLM system itself. In our case, XPLM was integrated with Siemens NX and CATIA V5 (see Figure 1).

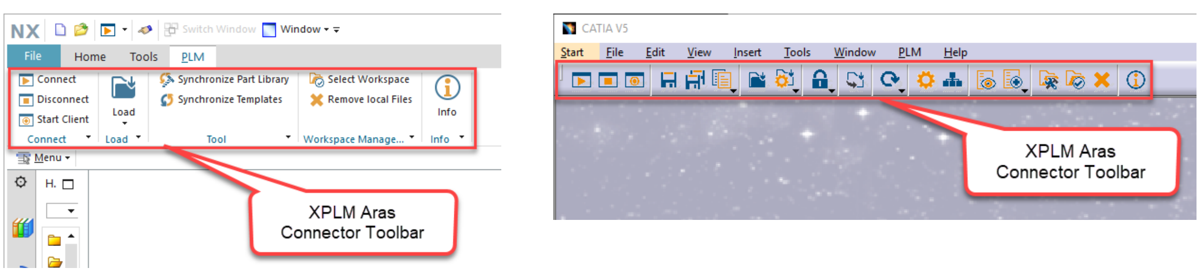

Figure 1. XPLM integration with Siemens NX (left) and CATIA V5 (right)

We adopted an agile development plan so that we can quickly maneuver to solve issues that either the students or the instructors have with the system. This led to many smaller quality-of-life updates that made the system easier and more effective for every party involved.

In the first implementation, a workflow and a lifecycle were developed to allow the release of weekly assignments. This portion of the system was administered by the instructor and was not visible to students. For each week activity an email was automatically sent out to the students. A student submission workflow and lifecycle were also developed to allow students to submit their assignments. First, the student was prompted to generate a submission item by the weekly release notification. After the item was created, students were asked to create and upload a CAD model to the PLM system. To encourage student collaboration and participation, the workflow also allowed students to submit questions to the class in the form of comments.

However, user feedback quickly revealed that many of the steps felt redundant due to the use of workflow tasks. While these tasks are not trivial when students are beginning to learn the PLM system, they quickly became repetitive and unnecessary after a few iterations. In addition, instructors were also required to open the Student Submission item, then open the attached CAD Document, and then finally download the native CAD file. For these and other reasons, a decision was made to eliminate the Student Submission Item and its corresponding workflows and create a new system of submitting assignments based on the CAD Document item lifecycle available in Aras Innovator.

The CAD Document item was edited to include the properties that were previously available in the student submission item (see Figure 2). Two different views were created, one available to the instructors and one to students. The difference between the two views is the grade selection and the assigned creator property fields. On the student view, these properties are not visible, which allows the instructor to assign grades to a CAD Document that will be visible to, but not editable by the students.

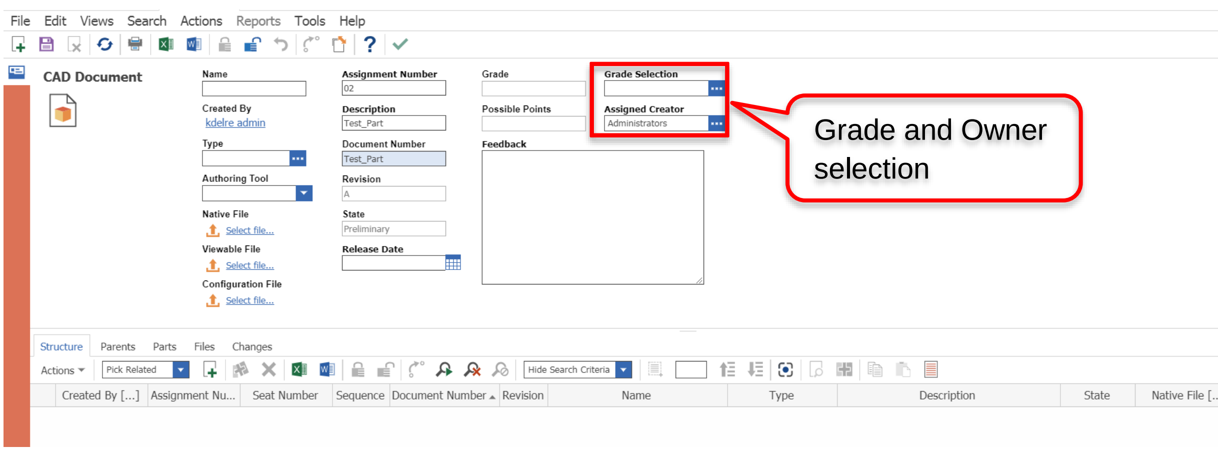

Figure 2 Updated CAD Document

The use of the CAD Document Item allowed the use of an updated version of the existing CAD Document lifecycle to manage the student assignments (see Figure 3).

The original lifecycle for the CAD Document item did not contain the “Graded” state that is shown in Figure 3. This added state is used by the instructor once a CAD Document has been graded, so that graded documents can be easily searched for and restricted by new permissions. These permissions only allow students to see the document and its newly added grade. They are not allowed to edit or to create new revisions of the graded document.

For our purposes, the existing lifecycle states “Preliminary” and “Released” were used. The “Preliminary” state is where all CAD Documents begin when they are created. The “Released” state is used by students to indicate that their document is ready to be graded. A document can be promoted to this state by both the student who created the document and the instructors. This feature allows the instructor to force release after an assignment is due to be submitted. In this state, the document cannot be edited, but students can create a new revision (which will be set back to the “Preliminary” state) to fix any mistakes that they may have missed when they originally released the document. This also allows the instructor to inspect previous revisions to see where students are having issues. The states “In Review”, “In Change”, or “Superseded” are not used. “In Review” would normally be used to determine if a CAD Document was ready to be promoted to “Released,” which typically involves someone other than the creator of the document to check for errors. In our system, the only two users that have access to a particular Item are the student that created it and the instructor. The “In Change” and “Superseded” states were not used because any changes that students need to make to a released document will be done with a new revision, which allows for a more condensed view of the changes and keeps all of the revisions associated to a single CAD Document.

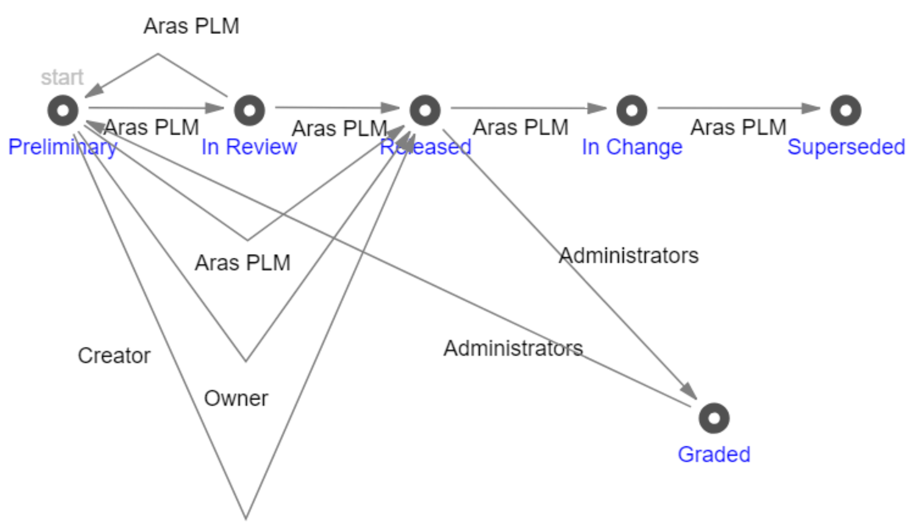

Figure 3. Updated CAD Document Lifecycle

Many of the updates made to the CAD Document item were also implemented on the Document item. The Document item is to be used by students to submit files (other than CAD) such as hand drawn sketches that have been scanned into PDF form. Similar to a CAD Document, a Document item has two separate views where the difference is the grade selection and the assigned owner property fields. On the student view, these properties are not visible, which allows the instructor to assign grades to the Document item that will be visible to but not editable by the students.

An additional modification made to the CAD Document and Document Item’s lifecycle was providing the Instructor (Admininstrator) with the ability to demote CAD Documents and Documents back to the preliminary state. This allows the Instructor to troubleshoot and provide administrative support in real time for students and delete items that may have been created by mistake and promoted to a state that does not allow for deletion.

Discussion

Aras PLM was deployed to CGT 103 Geometric Modeling Applications in the spring semester of 2019 with a simplified user interface as shown in Figure 4. CGT 103 is a three-credit hour Freshman level course that meets one day a week in a three-hour lecture/lab format with one additional hour reserved for distance learning. Lectures and lab assignments are pre-recorded and completed by students outside of class. Lecture content is discussed in class and lab assignments are initiated during the lab time and typically completed by students outside of class. Students are only provided the areas of Aras Innovator for which they will be utilizing in the course to eliminate confusion and frustration with the tool.

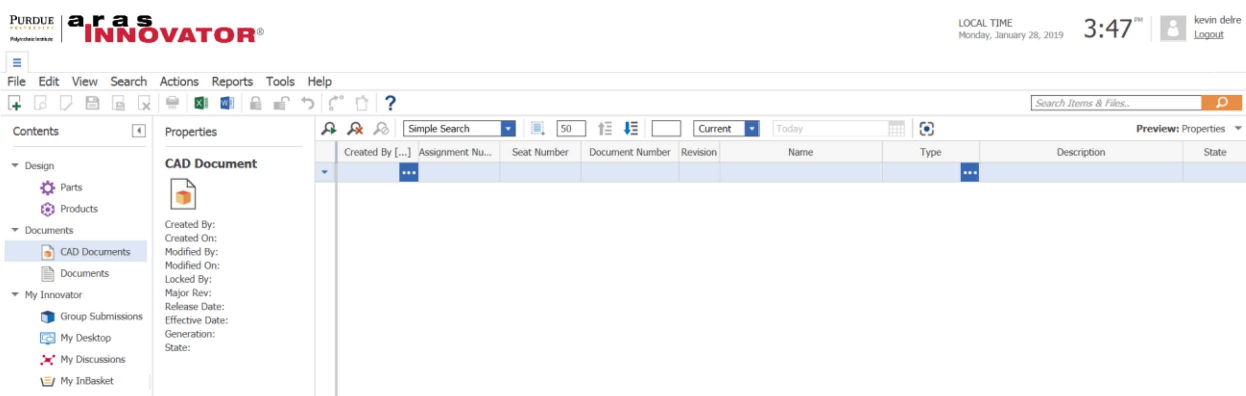

Figure 4. User interface for students

Within the first three weeks of deploying Aras Innovator in the classroom, students began to comprehend the need for a PLM tool in context CAD modeling and workflow. In weekly reflections students commented on the number of steps required to make a submission for grading yet understood the need for the process for accountability and traceability.

From an instructor perspective, it became clear that the submission workflow deployed originally would make it difficult to grade assignments in an efficient manner. Changes were quickly implemented to use the CAD Document lifecycle to submit parts for grading. Students simply had to promote their individual parts to “Released” to be graded. The instructor can in turn filter on the assignment number and released properties for grading.

An effective assignment naming convention is an important component for success, particularly if deploying the PLM system in a large class. Just as industry utilizes part naming convention to quickly identify types or categories of parts, the assignment naming convention leveraged to quickly identify the student who created the submission and the assignment being submitted. In our system, the assignment naming convention is assembled in the Name field by Aras by consolidating system information such as username and seat number with student entered information consisting of assignment number and description in the format below. Just as in an industrial deployment, the automation of the naming convention reduces user error and the time spent entering data into the system.

AASS_Username_Descriptor, where:
AA = Two-digit assignment number
SS = Two-digit seat number as assigned in the lab section
Username = Student login ID
Descriptor = Descriptive name given by student to quickly identify geometry

With our system, grading can be completed within the given lab section from the instructor station where students can be called up to provide feedback in real-time. Scores are recorded on the CAD Document Items within the system, then exported to Excel and subsequently imported into Blackboard, our system of record. Previous methods of grading required files to be downloaded from the LMS, or screen graded at each individual student's computer.

The ability to maintain security and permissions on certain attributes within an item is paramount, particularly if group submissions are implemented. Our system uses an edited version of the CAD Document item as the basis for student submissions, which allows students to use the release and revision commands to differentiate submissions. In the case of a single student, resubmissions are managed as new revisions of the original submission. Similarly, in a group submission, students can utilize version control to release a particular version for a project milestone grade, while continuing to work on other unreleased versions until the next milestone or the project's completion. Security is also important in the XPLM integration. In our case, custom scripts were used to ensure that when a model is generated using the XPLM connector, the CAD Document item that is created follows the assigned permission, which prevents all CAD Documents to be searchable by users that did not create the document. This provides the necessary security to meet FERPA requirements while simplifying the student interaction with the system by eliminating the need to enter search criteria to find their own work. Students only need to filter between data or assignments they have created themselves.

Conclusions

This ongoing study of the implementation of a PLM system in an academic scenario similar to the way it would be deployed in industry is challenging the way basic CAD data management and modeling have been taught in an academic setting. The concept of PLM is important for students in the technology field and specifically for students in majors with a heavy CAD component. Current learning strategies do not provide sufficient exposure to CAD in the context of PLM, which leads to the students' lack of experience with these systems and does not prepare them to effectively enter the workforce. By introducing an industry level PLM system into the college-level course administration, students will have an active involvement in PLM concepts and their associated workflows and processes. Our system could be the basis of a new strategy to teach PLM that will allow students to consistently interact with workflows, experience part release and revision in a PLM environment, and gain experience with key industry tasks.

From the preliminary results, observations, and user feedback, our solution seems to be an effective method for teaching PLM to students. It has garnered the interest of other instructors in upper level courses who expressed interest in using the system to administer separate CAD focused courses. Other instructors have also valued the introduction of PLM at freshman level, arguing that, since students are already gaining experience as PLM users as freshman, they will be better prepared for upper-level course that focus on PLM administration.

As future work, we are planning the automation of the workflows by developing scripts to control certain tasks. Similarly, we are designing a single master workflow to control all the current workflows so when a certain state is reached, all the items needed by the instructor and students are created automatically.

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