Industry Product Data Management (PDM) Tool Integration into Undergraduate Engineering Design Courses (Work in Progress)

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Abstract

The primary objective of capstone design courses is to provide students with a culminating experience that will prepare them adequately for industry or graduate studies. Project Data Management (PDM) software is ubiquitous throughout aerospace, automotive, energy, and healthcare companies to review and drive product design changes. PDM software centrally captures and stores all revisions to parts and assemblies through a controlled "check-in/check-out" process. Integration of enterprise-level PDM software in an academic setting helps to manage process flow toward meeting course objectives, particularly when the course is structured to mimic industry style product development groups. The ability to see individual contributions to a project allows course instructors to make a fair assessment of student effort and mitigate potential group conflicts.

Keywords

Product Data Management, PDM, Check-In/Check-Out, Enterprise Software in the Classroom, Capstone Design

Introduction

Engineering capstone design programs primarily provide the accreditation need articulated by ABET Criterion 5: "baccalaureate degree curricula must provide a capstone or integrating experience that develops student competencies in applying both technical and non-technical skills in solving problems"[1]. An additional goal of capstone is to provide students with a transitional experience from university to industry careers as practicing engineers.

Over 60% of capstone design programs participating in the 2015 capstone design survey report capstone design courses that require more than one semester or quarter of student effort [2]. Information transfer over multi-semester courses has inherent problems, notably the potential for catastrophic loss of information. The problems are further exacerbated when projects require significant communication from multiple organizations [3], as is common in many industry sponsored design programs.

Iteration on design models and initial refinement for manufacturing is the largest time contributor in the design realization process [4]. Many courses in the undergraduate curriculum use current industry standard software to familiarize students with the tools they will be using upon graduation such as Computer-Aided Design (CAD)[5, 6], Finite Element Analysis (FEA) [7, 8], and Computational Fluid Dynamics (CFD) [9, 10]. This software is also often integrated into capstone design project requirements to reinforce fundamentals and apply previous learning outcomes to a “real-world” problem in an environment similar to what engineers in industry experience in practice [3, 11]. Project Data Management (PDM) software is ubiquitous throughout aerospace, automotive, energy, and healthcare companies to review and drive product design changes and has been used for engineering student design teams with great results [12]. However, to our knowledge, and to the knowledge of Solidworks North America, PDM has never been deployed at an academic institution for instructional purposes.

Most major CAD software has a supported PDM tool that integrates seamlessly with their CAD clients: Solidworks – Solidworks PDM [13], Siemens NX – Teamcenter [14], Autodesk Inventor – Vault [15], and PCT – Windchill [16]. PDM software centrally captures and stores all revisions to parts and assemblies through a controlled “check-in/check-out” process. As PDM is not restricted to CAD models, all files involved in the design process can be centrally stored and assessed, and student editing permissions can be restricted at an individual or group level with ease.

With a plurality of reporting programs utilizing one or two faculty members for their capstone projects [2], PDM implementation offers effective tool to improve student-faculty interactions and simplify the assessment process. Large enrollment programs may be able to realize substantial improvement in project management, and significantly reduce the number of faculty hours focused on capstone design review and assessment. For example, in a companion paper, PDM deployment and the ability for instructors to monitor and control document workflow (Figure 1) is cited as a key tool for reducing capstone design faculty workload [17].

Methods

Beginning in the spring semester of 2019, PDM was implemented in a representative cohort of students participating in the capstone “build” class. A section of 49 students was broken down into 2 “product development teams” of 24-25 students each. Each team was further segmented into 5 sub-teams, each responsible for a representative sub-assembly, critical function, or testing/validation task.

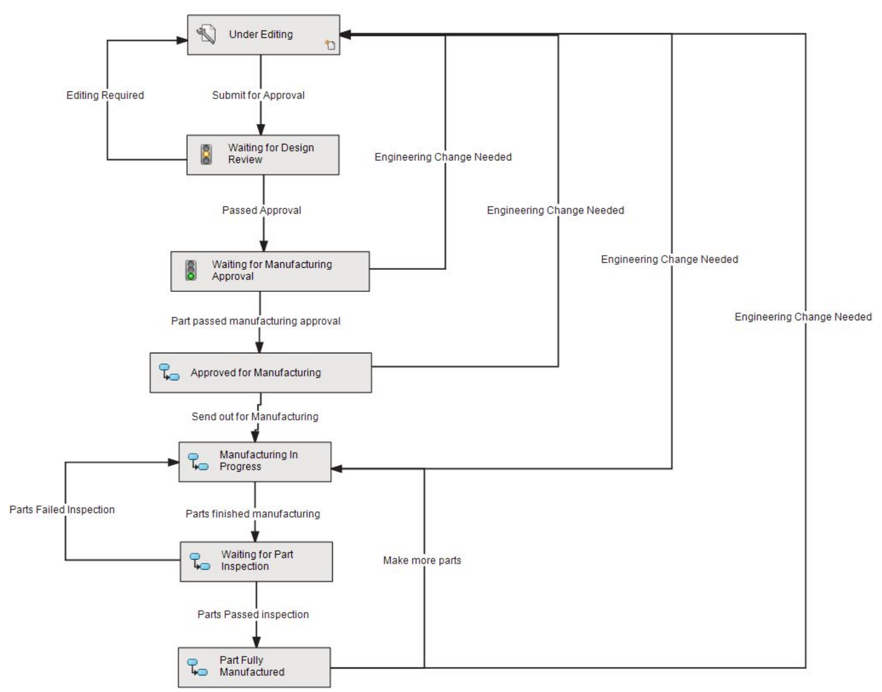

Figure 1. PDM document workflow control scheme. Student editing permissions are limited to parts in the “Under Editing” state. Students are able to transition states with the exception of manufacturing approval, which requires instructor or teaching assistant review.

Individual sub-teams met during weekly lab periods, with instructor supported full-team meetings occurring in place of a traditional lecture session. Sub-assemblies were assigned in a manner to require communication between sub-teams to determine deadlines and integration requirements. The setup ensured students fully utilize the check-out/check-in, revision history, and approval processes built into Solidworks PDM to successfully accomplish the project goals.

The teams were assigned a Solidworks PDM vault on the first day of class and given instruction on check-out and check-in procedures and general PDM best practices. A simplified workflow with instructor and/or TA approval waypoints (Figure 1) was implemented within the PDM framework. As students completed assigned tasks, components were for approval and either greenlit for manufacturing or returned to the students for further revisions with accompanying instructor comments on the necessary changes.

Event	V...	User	Date	Comment
Checked in	23	[illegible]	2019-04-11 22:20:21	
Checked in	22	[illegible]	2019-04-11 15:32:31	Add holes mounting housing
Checked in	21	[illegible]	2019-04-10 18:15:50	Changed bolt circle fro 4 to 3 holes
Checked in	20	[illegible]	2019-04-10 16:19:13	
Checked in	19	[illegible]	2019-04-10 15:23:22	
Checked in	18	[illegible]	2019-04-10 15:17:15	
Checked in	17	[illegible]	2019-04-10 11:20:09	Adjusted bolt circle by 45 degrees.
Checked in	16	[illegible]	2019-04-09 19:39:53	
Checked in	15	[illegible]	2019-04-09 17:35:41	
Checked in	14	[illegible]	2019-04-09 17:30:29	
Checked in	13	[illegible]	2019-04-09 15:46:04	
Checked in	12	[illegible]	2019-04-09 14:06:48	
Checked in	11	[illegible]	2019-03-26 12:22:51	Adjusted Bellow to Bellow dimension from 10.58 to 10.50 in.
Checked in	10	[illegible]	2019-03-25 18:47:47	Changed hole pattern to accomodate new tank.
Checked in	9	[illegible]	2019-03-15 14:51:38	
Checked in	8	[illegible]	2019-03-13 17:10:00	
Checked in	7	[illegible]	2019-03-13 15:54:44	
Checked in	6	[illegible]	2019-03-13 14:06:55	
Checked in	5	[illegible]	2019-02-21 14:24:06	
Checked in	4	[illegible]	2019-02-21 13:51:18	
Checked in	3	[illegible]	2019-02-21 12:33:52	
Initial tran...	2	[illegible]	2019-02-20 15:42:22	State changed by automatic transition.
Checked in	2	[illegible]	2019-02-20 15:42:22	
Created	1	[illegible]	2019-02-20 15:40:09	

Figure 2. PDM part/assembly revision log. Revision comments can be set as a requirement for any check-in of a modified model allowing for documentation of design process and providing a log of student participation.

Student project contributions and individual effort were assessed through PDM logs (Figure 2). Access to previous component revision enabled discussions of design evolution in response to changing customer needs and configuration changes.

Preliminary Results, Conclusions, and Next Steps

Preliminary feedback on PDM implementation from both the students and industry partners has been very positive. The capacity to roll-back designs to a previous state was particularly lauded by students for saving them countless hours when a design was overwritten or changed in error. The log of student activity can be accessed through a part or assembly's "revision history" (Figure 2) and it is easy to identify which students are either underperforming, or more likely, falling through the cracks created by overzealous teammates.

Due to the wealth of positive feedback, PDM is currently being implemented in the first half of the two semester design-build capstone experience to acclimate students to the software. Designs for Spring 2020 will be transferred from the appropriate team's "Design" folder to their "Build" folder for the upcoming realization course. An effective assessment tool is being developed to measure student involvement and learning outcomes based on PDM data.

As expected with initial classroom implementation of any new software, PDM has presented some challenges. Due to the computer management hierarchy at the university, faculty found themselves teaching in classroom computers to which engineering IT administrators had no access. Thus, SolidWorks PDM was not installed on these machines, and faculty had to use remote desktop to their office machines to display models on the PDM server in the classroom. A more common problem encountered by students is that once checked out through PDM, parts are inaccessible to others. If a student carelessly failed to check in a part at the end of a work session, other students could not access that part until it was checked back in. Nonetheless, these minor hiccups with PDM implementation were far overshadowed by its benefits.

Engineering student learning outcomes are typically assessed by comparison to external benchmarks because students coming into engineering course usually do not innately possess mastery at the outset. By contrast, assessment in industrial design is “ipsative”; based on improvement measured against an incoming baseline, which is different for each student. Industrial design instructors separate the innate talent one brings into a class from the skills learned or built in the course [18]. Since engineering capstone is a culminating experience where students apply preexisting knowledge, it is unique among the engineering courses because students come into the course with substantial relevant knowledge. Capstone, therefore, lends itself to ipsative assessment where students’ improvement over time can be evaluated in lieu of an assessment against an absolute benchmark. Typical engineering assessment techniques (tests, reports, presentations, etc.) are incompatible with ipsative assessment, but the ability of PDM to track the evolution of a design through time allows engineering faculty a new way to assess capstone design. This new approach will be explored in the future.

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References

1. ABET: Criteria for Accrediting Engineering Programs, www.abet.org, (2018)
2. Howe, S., Rosenbauer, L., Poulos, S.: The 2015 capstone design survey results: Current practices and changes over time. Int. J. Eng. Educ. 33, 1393–1421 (2017)
3. Joshi, S., Summers, J.D.: Investigating Information Loss in Collaborative Design: A Case Study with Capstone Design Project. Natl. Capstone Conf. 2010, Boulder, CO. No--51 (2010)
4. Albano, R.E., Keska, J.P.: Is Design Realization a Process? A Case Study. IEEE Trans. Components, Hybrids, Manuf. Technol. 13, 509–515 (1990). https://doi.org/10.1109/33.58852
5. Marunić, G., Glažar, V.: IMPROVEMENT AND ASSESSMENT OF SPATIAL ABILITY IN ENGINEERING EDUCATION. Eng. Rev. 34, 139–150 (2014)
6. Barr, R.E., Schmidt, P.S., Krueger, T.J., Twu, C.-Y.: An Introduction to Engineering Through an Integrated Reverse Engineering and Design Graphics Project. J. Eng. Educ. 89, 413–418 (2000). https://doi.org/10.1002/j.2168-9830.2000.tb00545.x
7. Steif, P.S., Gallagher, E.: Use of Simplified FEA to Enhance Visualization in Mechanics. In: Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition. American Society for Engineering Education (2004)
8. Howard, W.E., Musto, J.C., Prantil, V.: Finite Element Analysis in a Mechanics Course Sequence. In: Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition (2001)
9. Stern, F., Xing, T., Yarbrough, D.B., Rothmayer, A., Rajagopalan, G., Prakashotta, S., Caughey, D., Bhaskaran, R., Smith, S., Hutchings, B., Moeykens, S.: Hands-On CFD Educational Interface for Engineering Courses and Laboratories. J. Eng. Educ. 95, 63–83 (2006). https://doi.org/10.1002/j.2168-9830.2006.tb00878.x
10. Aradag, S., Olgun, U., Aktürk, F., Başıbüyük, B.: CFD analysis of cooling of electronic equipment as an undergraduate design project. Comput. Appl. Eng. Educ. 20, 103–113 (2012). https://doi.org/10.1002/cae.20378
11. Barber, T.: The Use of CFD in Capstone Senior Design Projects. In: 46th AIAA Aerospace Sciences Meeting and Exhibit. American Institute of Aeronautics and Astronautics, Reston, Virigina (2008)
12. Gidion, G., Buchal, R.O.: FOSTERING TEAMWORK SKILLS USING COLLABORATION SOFTWARE IN ENGINEERING DESIGN EDUCATION. Proc. 2013 Can. Eng. Educ. Assoc. Conf. 236–286 (2013)
13. Pdm, S.: Solidworks Pdm, (2016)
14. Siemens: Teamcenter
15. Autodesk: Product Data Management Software
16. PTC: Windchill PLM Software
17. Traum, M.J., Niemi, S.R., Griffis, M.W., Thomas, N.A., Sawyer, W.G.: Implementing an Effective Large-Enrollment Engineering Capstone Design-and-Build Program. In: Proceedings of the 2020 ASEE Southeastern Section Conference (2020)
18. Traum, M.J., Anderson, C.F., Pastore, C.M., Leonard, M.J.: Initial Lessons from Nexus Learning for Engineering Students Achieved Via Interdisciplinary Projects for Outside Clients. In: Proceedings of the Spring 2015 Mid-Atlantic ASEE Conference (2015)