The Application of an Engineering Design and Information Systems Case Study in a Senior Level Product Data Management Course

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Abstract

This study examines the use of an engineering design and information systems case study over a three week period in a senior level class covering the topics of product data management (PDM) and product lifecycle management (PLM). Students that have taken the course in the past have struggled with the sometimes nebulous and difficult to conceptualize concepts of both PDM and PLM. It was hoped that the application of a case study of this nature would help clarify the principles of these important topics. Students were assigned in groups to various roles as defined in the case, as well as given a specific scenario to examine. Their task was to analyze the case from a PDM/PLM perspective and provide solutions and recommendations that would resolve the issues their group/role faced. Upon conclusion of the project, the students were given a survey that caused them to reflect on the case and its possible benefits as an educational method. The results were promising, and showed that the students found the case to be very helpful in learning and understanding the principles of PDM/PLM. Mean scores from Likert instrument questions as well as comments from open-ended questions are shared in the paper. Although the study was limited to one class (n=18) of students in a specific topic of study, the implications for instruction strongly support the use of case studies and practical scenarios in technology education.

Keywords:
Case Study, Product Data Management, Product Lifecycle Management, Technology Education

Introduction

Product data management (PDM) is rapidly becoming a crucial consideration in many companies' and industries' strategic planning and process for storing, accessing, and controlling information related to the design and manufacture of products. PDM is also a key component of product lifecycle management (PLM), the process of controlling and leveraging important knowledge (data) from the time of product concept through product retirement and disposal. [1] The Product Data Management class in Purdue University's Department of Computer Graphics Technology is focused on exposing students to the theory and application of PDM/PLM principles as they are currently applied in industrial applications throughout the global marketplace. One of the challenges that the instructors of this class face is the embodiment of theoretical concepts in a way that becomes clear and "real" to the students. Often, the students will struggle with fully comprehending the importance of PDM/PLM processes, and with grasping the nuances of how each decision in the design process greatly impacts resulting decisions and directions in the production flow. As with many educational topics, theory and lecture-based instruction in this field can only achieve so much regarding student mastery and deep comprehension of the applications of the material. One potential solution to this instructional challenge is the use of real world problems set in interesting and motivational case studies. The use of such educational methods provides a context for the students to grasp and more fully understand the nature of the instruction. This "rich" learning benefits the students with a more concrete platform to build knowledge that allows them to be better prepared for the types of problems they will be asked to solve in the careers they enter after college.

Study Context

Product Lifecycle Management

Stark [1] defined PLM, "as a business environment for managing product information from initial development to obsolescence" (p. 2). The ability to leverage product data is especially relevant in light of the emphasis in the global marketplace for high quality, lean manufacturing, productivity, and increasing market share. Furthermore, the crucial need to effectively secure proprietary data while allowing efficient access to those who need it in a timely manner has driven the development of

PDM/PLM solutions. [2] The over-arching 'blanket' of PLM, covering the entire lifecycle from concept to grave, is hugely extensive and all-encompassing. All of the realms of production, such as needs analysis and planning, concept design, analysis, production planning, manufacturing, sales and distribution, customer support and maintenance, business/accounting, and product disposal and reuse, are included. The challenge of communicating across traditional chasms of isolation and separation within the enterprise are exacerbated by data formats and systems that were not designed to be shared. These separations are further complicated by global geographic differences, constantly shifting partners within the global enterprise, and current long-standing business practices and processes that hinder the flow of data across the product lifecycle. Product data management (PDM) is the aspect of PLM that specifically focuses on the development of the product (design, test, manufacture), and which provides the core information needed by engineers, suppliers, and production personnel. The continual development of "smart" computer aided design (CAD) database capability has enhanced both the value and importance of capturing and effectively leveraging product data throughout the lifecycle of that product. As more and more information is being stored within the 3-dimensional design database, there is a continuously growing need for effective communication ability, and knowledgeable engineers and technologists to leverage that intelligence.

Various industries have invested very large sums of money and resources in the implementation of PLM/PDM capabilities. CIMData [3] reported in 2007 that PLM technology applications were growing at a rate of more than 10% per year, an overall cost estimation of approximately $20 billion annually. Their estimate is that the growth rate for PLM investment will continue to grow at an average of 8.5% over the five year period from 2007 - 2011, achieving an annual price tag of more than $30 billion by the year 2011. This growing need and large investment of resources by many companies and industries will require professionals to be knowledgeable and competent in their understanding and ability to apply solutions to and within the PLM/PDM environment.

Case Studies as an Educational Method

According to some experts [4], the case method of instruction has been successfully employed by educators for many years, but only in certain fields such as medicine, law, and business. The use of case studies in engineering and technology education is a relatively new construct, but one that holds great promise. As Ertmer and Quinn [4] state, "The case method provides fertile ground for facilitating a reflective approach to learning" (p. 3). Newby, Stepich, Lehman, and Russell [5] noted that case study learning forces students to be actively involved in situations that are real or hypothetical that require analysis, evaluation, decision making, and planning of courses of action. The high level of activation in either individual or group settings tend to be highly motivational to students. They note, however, that the use of case studies in the classroom is often time consuming and requires effective classroom management by the instructor. Smith and Ragan [6] stated, "Case studies are particularly useful in learning to problem solve in situations in which there is more than one correct solution to the problem or in the more complex and subtle world of ill-structured problems" (p. 144). They also noted that case studies are highly motivational, can be effective in either group or individual environments, and are extremely effective in transferring learning to real world situations.

Another expert [7] claimed that situated case problems are often complex and multi-faceted, requiring the learner to deeply analyze in order to define the true problem before attempting to design a solution. This causes the student to be drawn into the context of the problem and justify their proposed solution at a deeper level. The differentiation often made by constructivist learning proponents is that learning must be meaningful to be effective. Meaningful learning can be defined as containing the attributes of being active, constructive, intentional, authentic, and cooperative. Active learning is that which requires engagement in meaningful tasks, allowing the learner to manipulate constructs in an environment and observing the results. Constructive learning involves the integration of new experiences with existing knowledge to 'construct' new learning. Intentional learning means that the learning is goal-oriented, causing the learner to think and reflect more in order to fulfill the learning goal. Authentic learning requires the task to be situated in complex, real world issues. Jonassen, Howland, Moore, and Marra [8] said, ". . . learning tasks that are situated in some meaningful real-world task or simulated in some case-based or problem-based learning environment are not only better understood, but also are

more consistently transferred to new situations" (p. 8). Additionally, Raju and Sankar [9] noted that the case study method of instruction is especially beneficial and strongly suited for students in engineering/high-technology related fields. Finally, meaningful learning is cooperative, requiring interaction among learners, often in group settings. Driscoll [10] noted that constructivist learning is based on the learning goals of reasoning, critical thinking, understanding and use of knowledge, and reflection. In order for true learning to occur, the student must be immersed in a complex and relevant environment that requires collaborative and problem-based learning. All of these constructs are deeply imbedded in case study methodology.

Research Model

The purpose of this research study was to imbed a case study into the curriculum of a senior level product lifecycle management/product data management course, and to measure the perceived impact of the case study on learning. Student perceptions were captured using a survey instrument containing both Likert-style response questions and open-ended comment questions. Creswell [11] noted that close-ended questions such as the Likert scale responses provide a means for comparing answers and allow for numerical analysis of data. Open-ended questions are useful for gathering richer qualitative data and for exploring deeper response possibilities. Gall, Gall, and Borg [12] also supported the use of Likert scale instruments as a common and useful means of measuring participant attitudes.

Methodology

The Computer Graphics Technology 423 class is a three-credit, semester long course designed to instruct students in the theory and application of product data management (PDM) within a product lifecycle management (PLM) context. The types of data generated and used in the product lifecycle are discussed, as well as the current tools and methodologies in the management of product data. Strategic approaches to system analysis and implementation techniques for using PDM as the foundation for supporting a company's product development cycle are key topics. The course learning outcomes for this class are as follows:

- To develop a significant understanding of the concepts, applications, and procedures involved in the controlling, protecting, and accessing product definition data.
- To understand and apply PDM technologies in a PLM environment.
- To develop hands-on experience in PDM from the end-user perspective, simulating the industrial environment.
- To develop hands-on experience in PDM from the product manager perspective, including product definition and project management.
- To develop familiarity in PDM from the IT administrator perspective, including infrastructure design and system implementation.
- To prepare for leadership responsibilities in industry through group tasks and responsibilities emphasizing teamwork, planning, and ethics applications in a project management environment.
- To develop necessary written and oral communication skills through course assignments and presentations.

Students in the class were asked to participate in a three week case study assignment and were assigned to a group that addressed the defined problems. The assignment included analysis of the stated case problem from the perspective of the role assigned to each student group. The students were tasked with identifying specific problem areas unique to their group role and developing suggested solutions utilizing PDM/PLM tools and methods. The assignment was broken into two distinct problem sets, as defined by the case. The first of these was a design issue involving the development and quality of the product in question, and the second was an information systems case that involved data and communication issues within the company. The four group roles for the engineering design issue were: design engineers at the company, members of the EPA/CARB board, product designer team members focused on quality issues, and members of the engineering management team. For the information systems part of the assignment, student group roles included: members of the strategic planning division at the company, representatives from the MIS division of the company, representatives from the manufacturing division of the company, and representatives from the design division of the company. A copy of the assignment is contained in Appendix 1.

Participants in the study were students (n=18) in the CGT 423 class during the spring semester of 2009. The students self-selected into four groups and were assigned to a role as defined in the case. The students were all fourth

year students completing their undergraduate major studies in aeronautical and astronautical engineering, computer graphics technology, mechanical engineering, or aeronautical engineering technology. There were 15 male and 3 female participants in the study groups.

The case study used in this research was the Yuquiyu Motors case study. This case involves both a design component and an information systems component, making it especially suitable for application in the PDM/PLM environment. The design problem examined the development of a two-stroke engine and its subsequent failure to pass required emissions testing prior to final production. Although the designated task in the case is for student to provide solutions to the technical design problem, for this application students were asked to propose solutions using PDM/PLM principles that would help prevent/resolve such an issue from happening or recurring in the future.

A second crucial consideration for the design aspect of the case was the "house of quality" application and focus. Quality improvement is a major consideration in PDM/PLM applications, and was a major emphasis for the student groups. Third, the case highlights the importance of constant and efficient communication at all levels within the company, another major emphasis of the product lifecycle. Finally, the student groups were assigned specific roles to play in the case, which focused them on various aspects of PDM/PLM theory and helped shaped their solutions.

Similarly, the second half of the assignment looked at the same issues from an information systems perspective. This part of the case helped the students focus on many issues of communication, data exchange, and information 'siloing' that occurs in common industrial practices. Upon conclusion of each of the design and information systems portions of the case study, the student groups were required to submit a written report summarizing their activities, difficulties encountered, proposed PDM/PLM solutions to the problem, management tasks, and strategic impacts to the company. An oral presentation was also prepared and delivered by each group for each of the two portions of the case.

Several weeks after the conclusion of the case study presentations and reports, the students were given a survey to measure their perception of learning and effectiveness of the use of the case study within the context of the class. The length of time between case use and survey completion was established to give students adequate time to reflect on the case and to provide an opportunity to consider the case usage within the larger context of the course curriculum. A copy of the survey instrument is contained in Appendix 2.

Results

A 20 question Likert scale survey was administered to the students. Table 1 shows the question and mean score results for the responses from the students. The possible responses for the participants to each question were Strongly Disagree (value = 1), Disagree (value = 2), Neutral (value = 3), Agree (value = 4), and Strongly Agree (value = 5). The questions were developed in an attempt to measure various constructs multiple times. Two questions (1, 14) were asked regarding the perception of difficulty in learning the overall course subject matter. Several questions (8, 12, 15, 18) were directed at measuring the students perception of effectiveness of the case study in relating to PDM/PLM concepts in the real world. Multiple questions explored the use of the case in helping develop various skill sets in the students. Questions 5 and 13 addressed team building and teamwork interaction. Question 16 examined problem-solving skill development, and question 20 measured student perception of communication skill improvement. Motivational, self-efficacy, and student enjoyment aspects were addressed with questions 3, 6, 10, 11, and 17. The aspect of case impact on the success of the class was explored with questions 2, 4, and 7, and level of perceived student effort was probed with questions 9 and 19.

The open-ended questions were developed to capture the students' overall perspective of the class, learning preferences, and suggestions for course improvement. Several of the questions were specifically focused on the use of the case study (questions 27 and 28) and are reported on here. Another question that elicited case study relevant responses (questions 26) is also described in the following paragraphs.

Question 27 (How beneficial would you rate the use of multi-media case studies in your learning the material presented in the course?) received many favorable and interesting responses. 17 of the 18 respondents were positive regarding the use of the case study in assisting in course learning. Responses included the following:

> ". . . the way problems are solved in the real world."

	Survey Question	Response Mean
1.	Product Data Management/Product Lifecycle Management are concepts that are difficult to learn.	2.72
2.	The Yuquiyu Motors case helped clarify PDM/PLM concepts.	4.00
3.	The Yuquiyu Motors case was interesting and motivating to me.	3.67
4.	The case study was important to the success of this class.	3.72
5.	The Yuquiyu Motors case helped me develop my team-building and interpersonal skills.	3.83
6.	Using the Yuquiyu Motors case helped stimulate my interest in PDM/PLM topics.	3.72
7.	I learned more in this class because of the Yuquiyu Motors case.	3.94
8.	The Yuquiyu Motors case helped me realize the types of problems with PDM/PLM in the real world.	4.11
9.	The Yuquiyu Motors case required me to be more persistent than other assignments to find solutions.	3.72
10.	The use of the Yuquiyu Motors case helped me develop my confidence that I can be successful in my career.	3.22
11.	I enjoyed using the Yuquiyu Motors case study as part of the class.	3.78
12.	The Yuquiyu Motors case seemed like a real problem, not a made up class exercise.	3.22
13.	Working in teams on the case study was beneficial to me.	3.94
14.	PDM/PLM principles are difficult to fully understand.	3.00
15.	The Yuquiyu Motors case helped me understand how data flows through the enterprise.	4.00
16.	The Yuquiyu Motors case helped me develop my problem-solving skills.	3.50
17.	I enjoy working with real world problems.	4.28
18.	The Yuquiyu Motors case helped me understand the importance of roles in PDM/PLM.	4.28
19.	The Yuquiyu Motors case required me to work harder than other assignments to successfully complete it.	3.50
20.	The Yuquiyu Motors case helped me develop my communication and presentation skills.	3.67

Table 1. Likert Scale Survey Questions

". . . gave us a real life example to work from."

"On a scale of 10 I would say a 9. It really helps seeing how this works in a work environment."

"It helped trying to put a real world aspect to it and talking about it in groups."

"It was beneficial in the way that it got me thinking about PDM/PLM without anyone telling me anything. Therefore I could try to understand the PDM/PLM issues on my own."

". . . instead of just hearing the information, we got to use the information. Hands-on experiences help me learn better."

". . . the case study could be an invaluable resource for developing understanding."

There were a few suggestions for improvement included in the responses for this question. They included:

> "The case study was interesting, but honestly I don't think it was deep enough or taken seriously enough to have a huge impact on understanding the material."
>
> ". . . things seemed jumbled and not so easy to locate on the website."

Question 28 (How useful did you find the use of student groups/teams to solving the problems presented in case studies?) was specifically asked to measure the benefit of teamwork/teams in solving the case assignment. Again 17 of the 18 participants felt that working in groups/on teams was an important aspect of the assignment. Following are several of their comments:

"I learn a lot from teammates . . ."

"The group was really helpful to me in understanding the course material."

"Working with many brains trying to solve a problem in a case study made it possible to find a better solution to the problem."

"It was very useful to see how others were understanding/approaching the problem."

". . . some of the people in the group had different backgrounds/perspectives on issues that really helped to form ideas."

Two suggestions for improvement included comments that no more than 3 students per group would have provided a more effective experience, and that each member of the group needed to be involved/invested for the group to be effective.

Seven of the respondents (39%) specifically stated that the case study was the most helpful aspect of the class (Question 26: What part(s) of this course did you find to be most helpful to you in learning the material?). Several of the comments are listed here:

"The case studies were helpful. It made us become problem solvers."

"The case studies. Looking at the real world and applying what we have learned in class."

"The projects with case study were most helpful. . ."

Discussion

The results of both the Likert scale questions and open-ended questions seem to support the concept that the Yuquiyu Motors case study was effective in this PDM/PLM instructional scenario, as well as supporting the construct of the usefulness of case studies in educational settings in general. The mean response scores for the Likert style questions show strong support for the case method. The questions that specifically focused on case studies and class learning (questions 2, 4, 7) received response scores ranging from 3.72 to 4.00, which indicated fairly strong agreement for this construct. Questions 8, 15, and 18 looked at the case study and its ability to help clarify PDM/PLM principles. The scores for these questions ranged from 4.00 – 4.28, showing significant support for this construct. Questions 5 and 13 tended to show moderate support (3.83, 3.94) for the idea that the cases helped with team building and teamwork skills. It should be mentioned that this construct could potentially be strengthened by using the case study for a longer period in the class than the three weeks allocated in this study. This might also address the student concern mentioned in the open-ended response above to question 27, where the student described the case work as not "deep enough" or "taken seriously enough" to provide more significant learning. The moderate responses regarding development of problem-solving skills and communication skills (Question 16, 3.50; Question 20, 3.67) while positive, could perhaps also be strengthened by a longer duration/more rigorous application of the case study in the course curriculum. Student preferences were analyzed in questions 3, 6, 11, and 17. The first three of these questions were focused on the enjoyment/benefit of the use of the case in the class and received moderately positive scores (3.67 – 3.78), indicating that the use of the case was beneficial and potentially describing a greater need or desire for such educational methods in the future. Question 17, looking at the desire to use real world problems in the class, received very strong support (4.28). Interestingly, although the students reported enjoying the use of the case study, they also responded to questions 9 and 19 that the use of the case caused them to work harder and apply more effort to solving the problem than other types of assignments. This highlights one of the key benefits and motivational aspects of using case studies in the classroom.

The results of the open-ended questions also support the use of the case study method. As mentioned earlier, meaningful learning occurs when educational tasks are active, constructive, intentional, authentic, and cooperative. The comments highlighted above indicate strong support for each of these constructs and are reinforced by the 94% (17 out of 18) of students that enjoyed or felt they benefitted from the use of the case study in this class. These results have significant impact for educators. As has long been realized be teachers in business, medicine, and law, the use of case studies in the classroom provide a level of learning that involves a much higher order of cognitive activity. This level of cognitive learning would be very beneficial if regularly applied in the realms

of engineering and technology, two areas that occasionally get "stuck" doing rote problem sets or exercises that are mired in lower-order cognitive activity. Of course, resource limitations and the need to develop competency with technological devices sometimes hamper the level of realism that can be applied in a 'hands-on' course, but the judicious application of case studies in technological fields could be hugely beneficial. Many, if not all students would benefit from the application of real world scenarios, ill-defined problem activity, and deep analysis of issues that would come from such applications. Furthermore, students that underperform in the technology or engineering classroom due to a mismatch with traditional lecture approaches to learning could benefit from the case study educational approach. Finally, underrepresented segments of the population might find engineering and technology fields of study more palatable given this approach to instruction.

Conclusion

This study analyzed the use of a design and information systems case study in a high-level product data management course. Results of a student perception study showed strong support for the use of cases in technology education, and highlighted potential educational benefits for many students. It is hoped that future research in this area will include a broader segment of the general population, explore potential uses as a remediation tool, and explore the possibility of the use of case studies as a means of expanding the engineering and technology teacher's "toolbox" of instructional methods.

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Appendix 1. Case Study Assignment

CGT 423 Mini Project Spring 2009

The purpose of this assignment is to begin looking at problems from the PDM/PLM perspective. This project will include team decision making, analysis, and written and oral documentation.

Each group is required to do the following:

- Analyze the Yuquiyu Motors problem (design and information systems) from the perspective of the role assigned to the group
- Provide a logical and clear written report of the nature of the problem and how appropriately applied PDM/PLM solutions will help resolve the problem.
- Point out specific problem areas that may be unique or especially troublesome for your group's role.
- The summary report should include a description of the activity of the group. Include all relevant interactions. Discuss difficulties encountered and how they were overcome. Explain the process involved in applying PDM/PLM solutions and how they might impact a user. Describe management tasks that would be involved in the solution. Explain why and how certain roles would be assigned and why these assignments are strategic to the success of your company. Include a time log sheet of how much time was spent by each member of the group for each task undertaken.
- Prepare and present a 10 minute (maximum) oral presentation each of the two weeks fully reviewing the group's project activities and results.

Projects will be graded on theoretical accuracy (PDM/PLM) (30%), proposed solution effectiveness (30%), written report quality (15%), oral presentations (15%), and overall professionalism (10%).

An electronic copy of all documentation will be submitted at the time of the presentation. A written copy of the report should also be submitted at the same time. Project presentations will be made during class time on Mondays during Weeks 4 & 5 (February 2 & 9). All reports and documentation are due on Monday, February 9.

Appendix 2. Case Study Survey Instrument

Yuquiyu Motors Case Study and CGT 423 Class Questionnaire

1. Product Data Management/Product Lifecycle Management are concepts that are difficult to learn.

Strongly Disagree Disagree Neutral Agree Strongly Agree

2. The Yuquiyu Motors case helped clarify PDM/PLM concepts.

Strongly Disagree Disagree Neutral Agree Strongly Agree

3. The Yuquiyu Motors case was interesting and motivating to me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

4. The case study was important to the success of this class.

Strongly Disagree Disagree Neutral Agree Strongly Agree

5. The Yuquiyu Motors case helped me develop my team-building and interpersonal skills.

Strongly Disagree Disagree Neutral Agree Strongly Agree

6. Using the Yuquiyu Motors case helped stimulate my interest in PDM/PLM topics.

Strongly Disagree Disagree Neutral Agree Strongly Agree

7. I learned more in this class because of the Yuquiyu Motors case.

Strongly Disagree Disagree Neutral Agree Strongly Agree

8. The Yuquiyu Motors case helped me realize the types of problems with PDM/PLM in the real world.

Strongly Disagree Disagree Neutral Agree Strongly Agree

9. The Yuquiyu Motors case required me to be more persistent than other assignments to find solutions.

Strongly Disagree Disagree Neutral Agree Strongly Agree

10. The use of the Yuquiyu Motors case helped me develop my confidence that I can be successful in my career.

Strongly Disagree Disagree Neutral Agree Strongly Agree

11. I enjoyed using the Yuquiyu Motors case study as part of the class.

Strongly Disagree Disagree Neutral Agree Strongly Agree

12. The Yuquiyu Motors case seemed like a real problem, not a made up class exercise.

Strongly Disagree Disagree Neutral Agree Strongly Agree

13. Working in teams on the case study was beneficial to me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

14. PDM/PLM principles are difficult to fully understand.

Strongly Disagree Disagree Neutral Agree Strongly Agree

15. The Yuquiyu Motors case helped me understand how data flows through the enterprise.

Strongly Disagree Disagree Neutral Agree Strongly Agree

16. The Yuquiyu Motors case helped me develop my problem-solving skills.

Strongly Disagree Disagree Neutral Agree Strongly Agree

17. I enjoy working with real world problems.

Strongly Disagree Disagree Neutral Agree Strongly Agree

18. The Yuquiyu Motors case helped me understand the importance of roles in PDM/PLM.

Strongly Disagree Disagree Neutral Agree Strongly Agree

19. The Yuquiyu Motors case required me to work harder than other assignments to successfully complete it.

Strongly Disagree Disagree Neutral Agree Strongly Agree

20. The Yuquiyu Motors case helped me develop my communication and presentation skills.

Strongly Disagree Disagree Neutral Agree Strongly Agree

21. What teaching styles do you find most helpful in learning new material (for example, lecture, distance learning, PowerPoint presentations, multi-media case studies, group projects, etc.)?

22. Do you prefer to work alone or in groups to solve problems? Why?

23. What suggestions do you have for enhancing your learning experience in this course?
24. How do you perceive that you might use the information learned in this course in your future work environment?

25. What part(s) of this course did you find to be most interesting?

26. What part(s) of this course did you find to be most helpful to you in learning the material?

27. How beneficial would you rate the use of multi-media case studies in your learning the material presented in this course? (Please explain in detail the benefits or non-beneficial aspects)

28. How useful did you find the use of student groups/teams to solving the problems presented in the case studies? (Please explain in detail the ways in working with other students in groups was helpful or not in your learning the course materials)

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