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EXPLORING FEATHERWEIGHT INDUSTRY PLM SOLUTIONS FOR ACADEMIC USE

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ABSTRACT
There is no doubt that PLM (Product Lifecycle Management) solutions are improving data sharing and decision making during product development in industry and beyond. CAD (Computer Aided Design) and document data are tied into product BOM (Bill of Material) structures, revision control is effective and change orders are well managed. This is appropriate for a professional environment with experienced design engineers, working on a project that often has a long life. However, undergraduate design engineers lack experience, working in many informal environments on projects with a short life. In many student group projects, data can be poorly controlled and decision making can be *ad hoc*. It can be suggested that students need PLM or PDM (Product Data Management) software to remedy this problem-many solutions, however, go beyond the scope and technical skill level of many student projects, with little benefit in short time scales. Even lightweight solutions are geared towards SME's (Small to Medium Enterprise) as opposed to a handful of students working on a 6 month project. There is a steep learning curve in effectively using current PLM/PDM software. For students, product data management needs to be intuitive and second nature; a featherweight solution is required. Students require the system to have an appropriate attitude and behaviour to CAD data storage, revision control and decision making in order to use advanced PLM systems effectively. This way of working can improve the quality of group design projects as well as giving graduates the basic skills to approach PLM themes professionally in their industrial careers. This paper explores the approaches and technologies available to give students the necessary skills for effective product data management.

Keywords: Product lifecycle management, product data management, group design projects

1 INTRODUCTION

PLM solutions allow designers and engineers to efficiently manage the lifecycle of a product, from concept design to market and disposal. PDM forms part of an effective PLM system, tracking the changes to product information during its lifecycle. It's an increasingly important system as product development has become increasingly complex. Aerospace and automotive design engineers benefit from PLM as they manage large, complex assemblies but the same is applicable for product designers who face the 'engineering challenges of developing new products for global competitive markets' [1]. For example, a consumer vacuum cleaner could have two or three variants of one model in the UK; an entry level model on one end with an advanced expert model (with added features and accessories) on the other. A US version of the same product would have to be different, firstly the motors would have to be swapped out and the cleaner head design would have to change to meet ASTM requirements. The design changes become even more complex when you consider product versions in the Far East. Nonetheless, all these variants share and reuse common parts and data, which need effective management. Records of change are not only important in the design phase, but also the manufacturing and in-use phases. Problems with existing parts can be investigated and the necessary design or tooling changes can be reviewed and approved using modern PLM systems. This requires collaboration with manufacturers, suppliers and the design team which is enhanced through PLM. Many modern PLM systems are integrated into their native CAD systems, to allow seamless version control between the two environments. This is a particular advantage over simplified PDM/BOM management systems, which are not integrated with CAD data; they rely on manual input or exported

BOM spreadsheets, which can lead to increased administrative work and potential error. Thus, integrated systems should free the designer from organising and tracking design data. This integration allows product data (CAD files, reports etc.) to be stored and accessed from a database or 'vault', improving efficiency in data sharing within the design team. However, Karniel et al [1] argues that the complexities of PLM tools have increased. New tools and 'versions are released continuously with new features to account for new emerging business and engineering needs and new technologies'. With this increasing complexity, many PLM providers offer 'lightweight' versions of their current solutions. Within the context of a large, global organization PLM solutions need to integrate with (or replace) existing practice. The PLM solution is complex and has to be customised to the organisations needs. In contrast, lightweight PLM is an out-of-the-box solution, geared towards SME's that have simpler supply chains and smaller design teams. Despite being easier to implement and use, with less scalability, lightweight PLM solutions are still business focused; the easier setup is a return on investment. A breakdown of this can be seen in Table 1.

Table 1. A breakdown of requirements against PLM 'types'

PLM type/requirements	Heavyweight PLM	Lightweight PLM
Appropriate Industry level	Large global industries with multiple sites, overseas manufacturing and distribution	Small to Medium Enterprises, sometimes with internal manufacturing and distribution
Potential Cost	Large financial investment with incurred costs from server and PLM support	Small financial investment, some cost are incurred from server and PLM support but some solutions are 'on-demand' or cloud based.
Integration with current practice	Integrated into current business practice with dedicated support from CAD/software vendors	Often an 'out-of-the box' solution, with some support from CAD/software vendors
Implementation	Could take months to integrate in all aspects of the business and train appropriate staff	An 'out-of-the-box' solution can be implemented and staff trained in a matter of weeks.
CAD Integration	Often integrated with high-level CAD packages (e.g NX, Catia)	Often integrated with lightweight CAD packages (e.g SolidEdge, Solidworks)
Ease of Use	Difficult. It has to be customized to current business practice and work multiple levels (CAM, CAE, Inspection, manufacturing change orders etc.)	Medium. An out-of-the box solution is pre-configured, but still needs integration to CAM and CAE elements.
Scalability/Complexity	Large. Many solutions integrate email communication, scheduling and planning, part review and discussion, links with reports and business documents as well as core engineering integration (Part revision/control, CAM, CAE etc).	Medium. Some solutions do allow an element of email/review integration, but primarily focus on core elements (part revision/control, CAM, CAE)

There is an emerging case to introduce concepts of integrated CAD and PLM within academic teaching. After all, students need to use CAD, work in design teams and share data effectively. Some software providers (such as Siemens and PTC) have academic programs that support the provision and teaching of CAD within Universities. They can offer lightweight PLM systems integrated with their current academic CAD packages; however this paper argues that even a lightweight PLM system may not be the most effective solution for an academic environment.

2 PLM WITHIN THE ACADEMIC CONTEXT

Like SME's, Universities may not benefit from a full, integrated PLM solution. In this aspect they have common traits such as cost barriers, staff training, process change and integration with existing software [2]. As with small companies, information systems are not adopted-with information sources getting lost or stored in multiple locations [2]. They seem to share *resource poverty* [3], the costs of implementation, training and paying in specialist PLM staff [4] are inhibitive. On top of this, they share the common problem that 'people need to be *diverted* from their normal task to enter and maintain information about the product' [2]. Many Universities have implemented PLM/PDM solutions successfully. For example, the University of Leicester [5] use NX and Teamcentre within their Space Research Centre, however it is targeted more at research project level, rather than undergraduate. The Belgorod Shukhov State Technological University [6] and Irkutsk State Technical University (ISTU) [7] teach PLM at a high level, with a focus on graduate skills in the aerospace and construction sectors. The Karlsruhe Institute of Technology (KIT) have recently embedded CAD practice with PLM. Their recent conference paper [8] comments on aspects of accessing PDM from private laptops, student numbers and changing IT-environments-elements of which are discussed further in this paper.

2.1 Academic teaching

Mechanical Engineering students need to learn how to use CAD software effectively, either through teaching sessions or independent learning. It is necessary for many of the design projects they undertake and a core skill for graduate employment. At Bath, the students learn basic CAD practices using Solid Edge [9], a lightweight and relatively user-friendly package. It is one of two Siemens CAD systems available to students; Solid Edge is geared towards education and SME's whereas NX [10] is a more advanced system, utilised by heavyweight automotive and aerospace industries. It is important to note that students are never *trained* to use Solid Edge, but are *taught* the fundamentals and skills that apply to many other CAD systems. With this methodology, it is found that some students naturally progress to using NX in their final year projects-without direct teaching provision (the students use online tutorials). This is the case of the Team Bath Racing-Formula Student (FS) team, who utilise NX in the design and development of their car. In 2012, a feasibility study was conducted to implement a PLM system for the FS team to use. Although many of the students (70%) [11] were competent with file management; it was found that 53% of the student team found version control of their files to be unclear [11]. As a result, the students have created their own system, known as BAPS (Bath Automotive Part System). Students were introduced to two trial PLM solutions, chosen under the needs and requirements of the FS team. Although students were happy with the general usability and user interface aspects of the packages, they preferred the current system [11]. This aligns well with the problem of *diverted* tasks [2]. To make PDM/PLM effective in the academic context, they need to be viewed as normal, frequent tasks in day to day file management. One of the main requirements of a PLM system is that it is 'easy to use' [11]. As it stands with CAD teaching, NX is too complex and overwhelming to teach at a first year level. With this in mind, an effective teaching model for PDM/PLM could be to teach the fundamentals (e.g. version control, BOM structures) with the intention that students can progress to using more advanced PDM/PLM solutions in their final year or graduate employment. It would be beneficial to introduce concepts of data management, using a basic PDM/PLM system early; however it would have to satisfy requirements in the academic context. PLM is great for accessing and sharing data with a team, but within the academic context it would be necessary to carefully control and restrict access. For example, it would be essential that only grouped students get access to their files, to prevent plagiarism. Third year projects are a good fit, as the group size is large, the number of groups are manageable and every design project is different. Also, all students undergo these projects; therefore the teaching of PLM/PDM would be wide-spread. It may be difficult to teach PLM/PDM to early year students, as their proficiency with using CAD is only just growing. Third year students would be more competent, and have the added bonus of having industrial placement experience. Teaching in this context could be provided as a workshop, supported by online resources.

2.2 Academic environment

There are significant differences between design environments found in academia and that of SME's. In small companies, engineers would often have their own permanent desk space and their own computer. The academic context is quite different; many students would not have the luxury of permanent desk space, they would have to access multiple-user computers in shared spaces. In some academic cases, there are not enough computers to satisfy the number of students [8]. In other cases, group space can be assigned; but this may be no more than a table in a small meeting room. In these circumstances, personal laptop computers may be utilised and therefore does not tie the group to their assigned space. Students can be free to meet and conduct project work within the University library or the Student Union; or work as individuals in a café or within the confines of their own bedroom. Therefore the PDM/PLM software needs to be accessible off-campus, an important requirement for the FS team [11]. Some packages are restrictive when it comes to this need, after all lightweight solutions have been designed for SME's and it is undesirable for confidential data to go 'off-site'. In this case it is necessary for CAD files to be 'checked-in and out' of the file management system; once again these are further *diverted* tasks [2]. There are web-based (on demand) solutions available which utilise cloud computing, one of the largest technological trends in PLM [12]. PDM/PLM solutions such as PTC Windchill [13] and Arena Solutions [14] already facilitate this need.

2.3 Academic project constraints

In an industrial environment, engineers would work on committed design projects for months, potentially years. The product would have a lifecycle that would need to be managed from concept development, to manufacture and disposal. Within the academic context, students would tend to work on design projects for a relatively short period of time whilst balancing other academic commitments. In most cases, many students have other coursework to complete on top of their design projects. On the other hand, Third year students have a committed design project, yet they have to balance design and business elements in their project over a period of 14 weeks. In many cases, excluding that of Formula student and similar competition teams, the product would never have a real manufacturing or in-use phase-only a hypothetical one. This reinforces the need for a PDM/PLM system to be easy to use and implemented quickly [11], to gain the most benefits from short projects. According to Eindhoven's endeavours in 2009 [15], it took 6 weeks to implement their PLM structure for their FS team; in which time their car was already being built.

2.4 Academic resources

Universities and SME's share *resource poverty* [3]. They have limited budgets, time to implement software and opportunities for training. CAD developers offer lightweight versions of CAD and PLM software to SME's as they tend to be cheaper, easier to use and quicker to implement and manage than more advanced software tools-this facilitates a good return in investment. In some ways Universities get an even better deal, as academic versions of CAD software are cheaper than their commercial counterparts-but academic budgets would be much smaller. The implementation of academic versions of PDM/PLM seems to be a grey area, in that only PTC provide dedicated PLM solutions for academic use. For example, NX and Solid Edge can be used with Teamcentre Express, but the system is a lightweight PLM solution geared towards SME's and comes at an additional cost. In the academic context, return of investment would be measured from enhanced student learning and better quality of design projects (unless the PLM solution was also utilised by academic research groups) [5]. The feasibility study with Team Bath Racing [11] explored the potential for PLM and PDM solutions to be made available to the team in return for sponsorship; however that only benefits the small number of students within the project. Another issue to consider is IT support and management, in which the PLM system needs to be manageable and sustainable [11]. Academic server support (for example, SQL and .NET integration) and licensing can be difficult to manage and take time to implement. There is also inherent cost in maintaining servers-that needs to be taken into account. IT teams and computer services have multiple commitments and can be often under-resourced. In an industrial context, problems with CAD and PLM installations would be dealt with rapidly. In an academic context it may take more time to deal with; which has more impact in short term student projects. At Bath, when it comes to installation and implementation of software, IT teams only have one window of opportunity in the year to re-build computers and install new software. Therefore, consultation and implementation of new or updated software has to be carefully timed. Similar to industry, most teaching computers within Universities are built to particular specifications. There is also consistency with multiple user workstations. This however, does not apply to student's computers [8] who may have personal laptops and desktop computers that exceed the specifications of university systems or fall below it. Many modern laptops and PC's could run CAD on a minimum system level, but there are issues with graphics card compliance, not to mention screen size and access to a mouse. Another resource issue is that students computers could run on Mac OS or Linux systems, which are incompatible with a Windows based CAD/PLM solution. Another similarity with SME's is that Universities tend to have one CAD package. This, in effect, restricts much of the choice available for selecting PDM/PLM solutions. Developers tend to design PDM/PLM solutions around their own native CAD package. Although the CAD software may facilitate academic needs, its PLM add-on may not.

To facilitate sharing different CAD files and formats, integrators are available for some packages. However, this can be difficult to implement, clunky to use and sometimes comes at an additional cost. Replacing CAD systems to facilitate the required PLM structure would have serious implications on teaching and research. There are some stand-alone products (for example, Arena) that have no affiliation with CAD, but this leaves the PDM solution and CAD software unconnected; more work; more *diverted* tasks.

3 REQUIREMENTS OF A FEATHERWEIGHT PLM SYSTEM

Having explored PLM within the academic context, a series of requirements can be suggested for a featherweight PLM system. This is compared to the requirements of existing PLM solutions in the market, as detailed in Table 2.

Table 2. A breakdown of requirements against PLM 'types' including a featherweight solution

PLM type/requirements	Heavyweight PLM	Lightweight PLM	Featherweight PLM
Appropriate Industry level	Large global industries with multiple sites, overseas manufacturing and distribution	Small to Medium Enterprises, sometimes with internal manufacturing and distribution	Small consultancies, Universities (research and undergraduate level)
Potential Cost/IT support	Large financial investment with incurred costs from server and PLM support	Medium financial investment, some cost are incurred from server and PLM support but some solutions are 'on-demand' or cloud based.	Small financial investment Academic pricing or free with CAD software. Ideally should be 'on-demand' or cloud based.
Integration with current practice	Integrated into current business practice with dedicated support from CAD/software vendors	Often an 'out-of-the box' solution, with some support from CAD/software vendors	Out-of-the box solution, inherently linked with CAD
Implementation	Could take months to integrate in all aspects of the business and train appropriate staff	An 'out-of-the-box' solution can be implemented and staff trained in a matter of weeks.	Used within context of CAD, with proficiency in a matter of days
CAD Integration	Often integrated with native high-level CAD packages (e.g NX, Catia)	Often integrated with native lightweight CAD packages (e.g SolidEdge, Solidworks)	Integrated with lightweight CAD packages with potential for non-native CAD support
Ease of Use	Difficult. It has to be customized to current business practice (CAM, CAE, Inspection, change orders etc.)	Medium. An out-of-the box solution is pre-configured, but still needs integration to CAM and CAE elements.	Easy. An out-of the-box solution that goes hand-in-hand with basic CAD practice
Scalability/Complexity	Large. Many solutions integrate email communication, scheduling and planning, part review and discussion, links with reports and business documents as well as core engineering integration (Part revision/control, CAM, CAE etc).	Medium. Some solutions do allow an element of email/review integration, but primarily focus on core elements (part revision/control, CAM, CAE)	Small. Must focus on core CAD related elements (part revision, data management)

4 DISCUSSION AND FURTHER WORK

The feasibility study for Formula Student PLM [11] suggests two web-based PLM solutions to consider for implementation, PTC Windchill and Arena. However, they are lightweight PLM solutions at heart and students prefer to work with what they know for short term projects. The students are able to effectively use NX with no teaching provision; on the back of their learning of basic CAD via teaching and project work using Solid Edge. Therefore, a similar model can be proposed to provide students with an insight into basic PDM/PLM methodology, so that they can apply these skills to a more advanced system in their final years. It is proposed that this methodology could be taught at third year level. Students would be working in groups for a long period of time, they would be competent in CAD and understand the design and business context of PDM/PLM integration. They would also have placement experience with industry, which may enhance the embracement of the software. Lightweight PLM may be too complex a system to introduce to students at this level, and does not work well with the remote-working nature of the design groups. Solid Edge has an add-on called Insight XT [16] as shown in Figure 1. Insight allows version control, interconnectivity with CAD files and documents. It's a basic PDM system, a featherweight, linked with CAD and Microsoft Sharepoint [17] used as a base. The advantage of this software is that students have access to it for free, and can be downloaded in the same way as Solid Edge. The data is presented in an organic and intuitive way, another current trend in interaction and visualization in PLM software [12]. Drawbacks are that the system relies on an installation of Microsoft Sharepoint as well as a SQL or .NET server, which may be more difficult to integrate into remote working. Aspects of external technologies and trends such as open source software, ubiquitous computing and integration into social networking [12] need to be explored further.

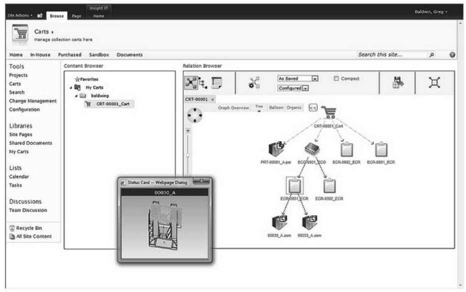

Figure 1. Screenshot of Solid Edge Insight XT

5 CONCLUSION

A basic featherweight PLM system has specific requirements which would be appropriate for academic use, but it does not come without technical difficulties and issues. A natural, basic CAD-integrated system which focuses on PDM fundamentals with minimal cost and IT/server support is required. Insight XT and BAPS will be investigated in the meantime. It may be that current PLM and PDM systems need more advancement in the trends discussed to be more user-friendly and compliant with an academic environment. More discussion is required between academia and CAD/PLM developers to flesh out the needs and requirements of teachers and students. It is hoped this paper will help facilitate that.

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