



NOT Reinventing the Wheel: Product Data Management (PDM) Software Utilized as a Feedback System for Students in an Introductory Engineering Graphics Course

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Abstract

This work in progress describes the application of a PDM solution to an introductory engineering graphics (IEG) course. PDM is one of many tools that our students will most likely encounter in their careers. Typical uses for PDM include; version control, common component libraries, templates, and design/documentation approval workflows. Nearly all industries and companies of any size have adopted PDM to decrease the cost of design. However, educational institutions have not widely implemented PDM into the education of our students.

The PDM system we chose to implement is specifically designed for CAD, and thus has feedback systems that the students will encounter in the workforce. This feedback allows for efficient drawing markup and direct review and commenting on 3D data. Traditional virtual learning environments and course management systems are not designed for CAD feedback. The ability to effectively communicate feedback to students is incredibly time-consuming, if not impossible. Therefore, utilizing a PDM system to provide feedback to students should increase their learning and also expose them to a tool used in industry.

Bringing new technology into the classroom is always difficult; we all face limited resources such as time and funding. In an attempt to decrease the resource requirements of implementation: our process of implementing a PDM solution in our IEG course will be shared. Particular attention on hardware requirements and selection, PDM setup and installation, training for instructional staff, and implementation lessons learned will be communicated.

1 Introduction

Engineering Graphics is a core course in mechanical engineering programs that is influenced by changes in computer graphics software.[1] However, the need to adopt and utilize product lifecycle management [2] and the subset, PDM software has been occasionally discussed in the literature for more than 15 years. In 2004, Frame et al. [3] emphasized the need for industries to adopt PLM/PDM approaches to design and also voiced concerns over the adoption into the curriculum of undergraduate mechanical engineering programs. There are three main concerns of yesterday for implementing PDM software: vendors do not recognize the need for PDM software in education, there is little if any teaching material for use with PDM, the cost of implementation may exceed available resources. [1] Today, in our review of resources, there appears to only be one implementation hurdle, the lack of literature and teaching materials for implementation, and the use of PDM software.

1.1 Functions of PDM Software in Industry

There are many functions of a PDM system, but perhaps the most commonly emphasized benefits to customers and users can be seen by reviewing PDM software pages of CAD software companies. Consistent features are safe and simultaneous use of data without concern for version control at multiple locations. [4],[5]

Scheidel [6] has described the five main functions of a PDM system as:

1. Document Management- creation, revision control, archiving
2. Product Structure Management-relationships between parts, assemblies, and drawings
3. Classification- numerical systems and meta-data which classifies and organizes objects
4. Workflow Management- business processes such as design approval and purchasing workflow
5. Project Management- activates and project management information such as the state of files or milestones

Buchal [7] has described PDM as having four main functions:

1. Data Vault and document management- control of files by "checking out," revision control, and archiving
2. Workflow and process management- specific roles can be assigned to team members, notifications of changes to components are communicated to the team, states such as checked-out, for review, and approved, business processes for design and even procurement
3. Product Structure- Bill of Materials (BOM), the integrity of file references for parts, assemblies, and drawings
4. Internet-enabled- access to shared CAD data over an internet connection

1.2 Functions of PDM Software in Educational Institutions

The use of PDM in educational institutions has been documented for many years now. Perhaps one of the deepest experiences with PDM can be realized in the Computer Graphics Technology Program at Purdue University. Kelley [2] describes a sequence of courses that provide a deep experience with the software.

Typical programs, especially those in the mechanical engineering department, do not mention the use of PDM in their course descriptions. It is unclear how deeply PDM has been embedded in the curriculum of most mechanical engineering programs. ABET criterion 3d, "an ability to function on multidisciplinary teams," and 3k, "an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice" [8] may motivate institutions to pursue the adoption of PDM software into their curriculum.

Collaborative projects that are common throughout the curriculum, for instance: capstone design courses, entrepreneurial courses, and IEG courses, would benefit from the safe, simultaneous use of CAD files provided by PDM. Students often devise unique systems that will be described later

to solve their file management problems. Most of these systems meet a few of the functions of a PDM system, but still provide issues and problems as they are applied to complex CAD file structures.

Undergraduates clubs would also benefit from a PDM system. Students are creative and have adapted to limited resources, but also run into limitations without a PDM solution. Common problems in clubs that would be addressed are: the usage of incorrect versions of components, an inability to effectively reuse components from designs produced in previous competitions, and little or no managed workflows for design approvals or purchasing.

The IEG course in a mechanical engineering program has the potential to expose students to a PDM system that students can utilize in their other courses, clubs, and individual projects. Another benefit of utilizing PDM in an IEG is to demonstrate and familiarize students with a tool that is commonly used in industry today. PDM exposure can occur as a replacement to the typical process of submitting work at our institution. Previously, students completed multiple CAD parts and drawings, saved them to a folder, compressed that folder, and submitted that compressed file to a learning management software (LMS). The work is then graded, and feedback is provided through the limited abilities of the LMS. A thoughtful implementation in the IEG has the potential to expose students to key functions of PDM:

- Product Structure- file references between parts, assemblies, and drawings will be maintained.
- Data Vault- access to multiple revisions and utilization of the proper version can be assured; also, graded work can be placed back in their folder for student review.
- Workflows- instead of submitting to an LMS, students can "check-in" their files to begin the grading workflow, and experience the same process as industry.
- Internet-enabled access- collaborative projects will allow students to share and retrieve each other's files without the potential of corrupting the file references or the limitations of physically being in the same location.
- Classification- student work can be classified as "needs- graded" or "modifications required." The files can also have meta-data associated with them to allow the tracking of a student's performance and later be used for educational research to observe the impact of different pedagogy and treatments on a student's work.

2 Comparison of selected "PDM" resources

Students and faculty have developed multiple alternatives to a true PDM solution. The utilization of non-PDM solutions is common and should be mentioned to provide an understanding of what students have been doing in the hopes of motivating the adoption of a PDM solution into all of their CAD efforts. The subcategories below are ordered to reflect an increasing amount of features that are found in PDM software. The last category includes several industry-standard PDM solutions that are available to educational institutions. All of the solutions below can be implemented for free or at a nominal cost per year, depending upon the license agreement that has been negotiated with a software provider.

2.1 Shared Drives

An important feature of PDM is to provide the ability to access files through an internet-connection and have the ability for multiple users to share the same files. Tools such as OneDrive, Google Drive, Sharepoint, Microsoft Teams, Slack, and numerous other solutions all allow for file sharing and collaboration.

Many students have experience with these tools, and it appears to be the defacto "PDM" system for their first attempt at collaborative design. Unfortunately, these systems do not ensure the integrity of file references, do not offer automated version control, and offer no workflow capabilities.

2.2 OnShape

The Professional version of OnShape has all of the features of a PDM system. It is unclear if this is available to universities at a reasonable price per seat. Based on their website[9], OnShape Standard is offered to educational institutions for free. Therefore, the features of OnShape Standard will be discussed. This software does allow for version control, the integrity of CAD file references, and web-based access to files. However, at the Standard level, it does not allow for workflows. It also does not appear to allow automated addition of meta-data to files.

2.3 GrabCAD Workbench

GrabCAD Workbench provides nearly all of the features of a "PDM" system. Users will realize the integrity of the product structure, benefits of a data vault (such as proper versions), and internet-enabled access. Several other features not mentioned here would allow for an efficient collaborative environment for CAD files, as detailed on the software feature page [10]. The large set of features may be one of the reasons why many clubs utilize this tool if they are unable to secure a full PDM software solution. An added benefit of this solution over GrabCAD is the support of all major CAD formats, a feature that most industrial PDM solutions do not offer.

This solution does have some classification abilities but cannot allow the easy addition of meta-data. It also does not offer exposure to a workflow that students will realize in industry.

2.4 Industrial PDM Systems

Each solution above has the potential to remove some of the issues that are common while utilizing CAD files. Some of the above systems may meet the specific needs of a course or club and should be evaluated before considering the implementation of solutions in this category. Through our implementation, it is clear that an industrial PDM system requires financial resources to purchase a server to act as a file vault and information technology(IT) resources to assist in the implementation of the PDM system in an educational environment. If the above systems do not meet user needs, or there is a desire to expose students to a workflow they will see in industry, then this category should be considered.

Both Autodesk Vault and SOLIDWORKS PDM Standard (SWPDMS) can be implemented at an educational institution for a nominal cost. Both Autodesk Vault and SWPDMS would require the purchase of a server for the file vault and assistance from the IT department. Autodesk Vault is free for educational usage, while SWPDMS is now included in the educational bundle that universities can purchase. This inclusion first occurred in the 2018-2019 version and exists today. Depending upon the agreement, the cost per seat can vary widely and is therefore not discussed.

3 Case Study- Implementation of SOLIDWORKS PDM Standard

Both Vault and SWPDMS offer full PDM functionality. Full functionality has been utilized in our curriculum to provide experiences to students that they can showcase at internships and in their careers. Only at this level of PDM software can workflows be created that will allow students to have an industrial experience while they receive feedback for their assignments. The implementation and usage of this solution is more time consuming than solutions 2.1-2.3. Resources for implementation and lessons learned through our implementation are also available at our course website <https://hub.wsu.edu/me-116/pdm/>.

3.1 Implementation process and issues

SOLIDWORKS offers two levels of PDM, Standard, and Professional. The Standard level is included in the licenses for SOLIDWORKS Professional and higher. Therefore, we chose a Standard installation over Professional. Our team utilized the SWPDM installation manual[11] to ensure we built the server properly and also ensured that we installed the correct components, such as Microsoft SQL Server Express. The general network structure we chose can be seen in Figure 1.[11]

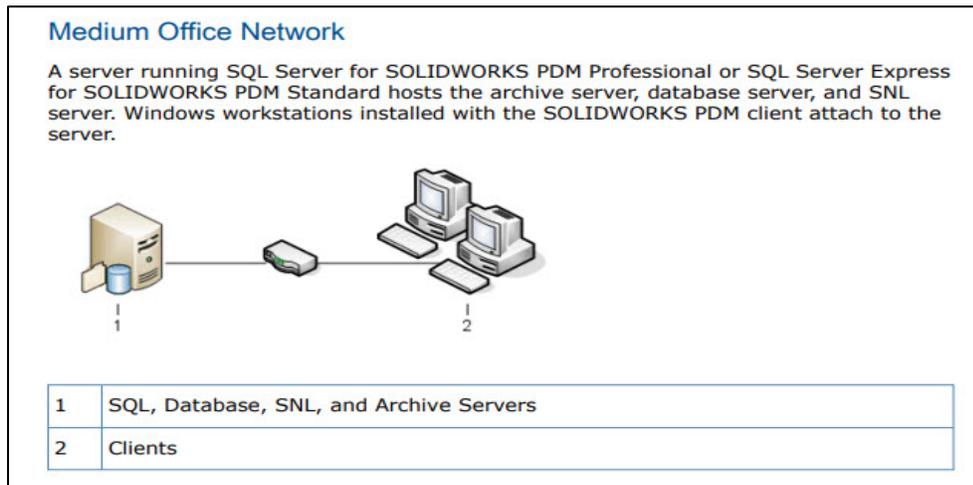


Figure 1. The computer network for SWPDMS implementation

An installation of SWPDMS requires us to determine several requirements at the beginning of this project-based upon guidance from the SWPDMS installation documentation and discussions with our IT department. The questions below guided server and network requirements, it is not exhaustive but rather an attempt to remove potential complications in the installation process.

For our installation, we asked the following questions to determine storage capabilities and network permissions:

- How much data will each student be posting each semester and how many students per semester?
- How long will we want to keep the data easily accessible?
- Who will have permission to use SWPDMS?
- Where will these users be located, in the CAD lab, on the academic network, off-campus, etc.?

Based on our usage, we decided on creating a server with four terabytes of storage. Our storage was based on the concept that students would upload a maximum of two gigabytes of data per semester, 105 students per semester, and storage for five years. Course data totaled approximately one terabyte of data; the additional three terabytes of data are initially intended for clubs to utilize, followed by researchers who choose to utilize SWPDMS.

Currently, we are working on a pilot implementation; therefore, we are only allowing students in our IEG course, instructors, and teaching assistants to utilize SWPDMS. We also decided to allow students to access SWPDMS from any location. This decision required significant IT support to implement. In hindsight, the initial pilot should have been implemented into just the LAN for the CAD lab. A LAN solution would have removed significant authentication and university firewall issues. However, by solving these problems, we can now invite more users for clubs and researchers to utilize SWPDMS.

3.2 Development of workflows

The main motivation for implementing SWPDMS is to expose students to a PDM workflow that they may see in their careers. We also wanted to utilize the suite of tools that SOLIDWORKS offers for grading and feedback to provide more efficient feedback as well as expose students to the feedback they will see in industry.

Students submit their files into their private folder that only they have permission to add and view files. Instructors and teaching assistants can also see and make state changes to files in their folder, such as "Passed Feedback" or "Editing Required." Figure 2 demonstrates the typical workflow for a file that is submitted. By having a state on a file, a student, or someone who is grading the work, can quickly see if attention is required. This type of system allows the student to make modifications to their work just like they would in industry and resubmit for approval.

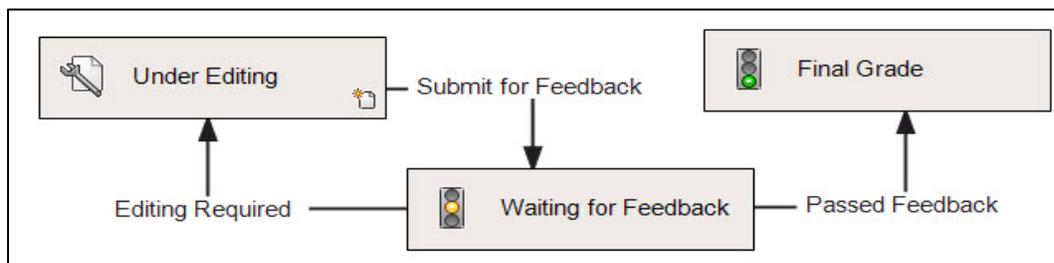


Figure 2. SWPDMS workflow for IEG course

While utilizing a PDM system, Windows Explorer has more capabilities and can allow a grader to see meta-data such as volume and weight, rotate and inspect the part including and even make a basic measurement. This customization occurs by creating a new Column in the Administration tool. A sample column setup is in Figure 3. Each column heading allows the sorting of the data and quick evaluation of the pertinent information. Scores, feedback, or grades can be provided with feedback through metadata or custom properties.

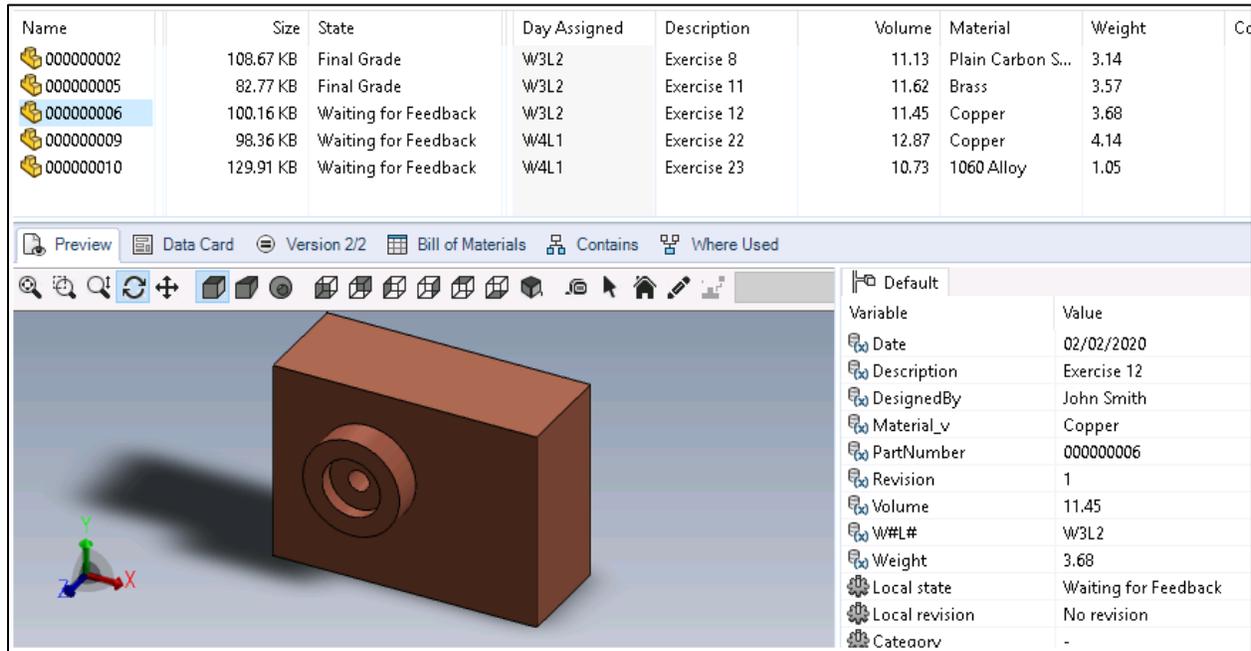


Figure 3. Windows Explorer interface while utilizing SWPDS, with custom columns and file preview tab on the bottom

Metadata can be placed into custom properties within the file, or it can be entered or automatically populated into the File Card when the file is first saved. The File Card is also customizable through the Administration tool for the organization's specific needs. Figure 4 is an image of a typical file card in our IEG course.

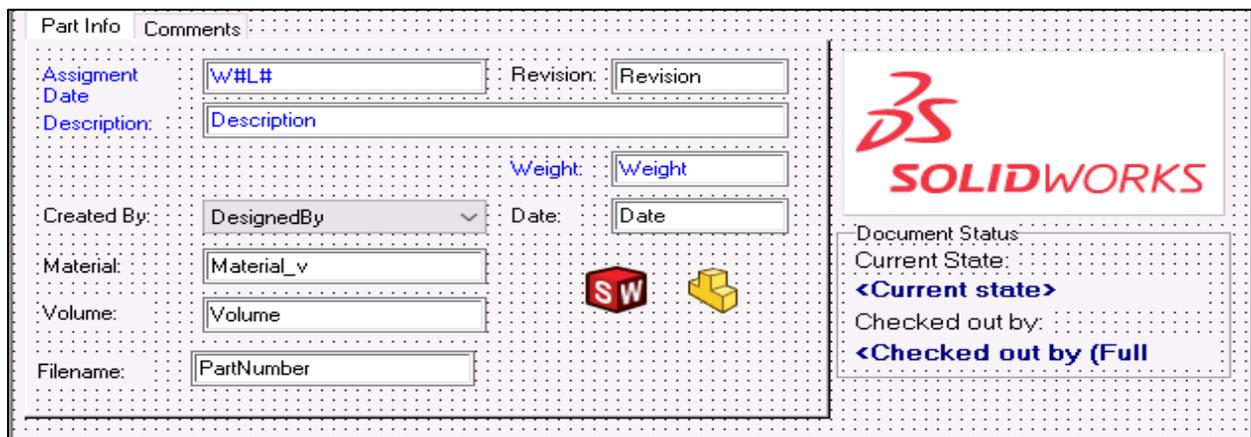


Figure 4. File Card from SWPDMs that students use when checking in a file

The column views, custom properties, metadata, and File Cards will require several iterations to meet the needs of our IEG. Fortunately, changes made to any of these items automatically update to all users, another benefit of PDM. Once an institution completes customization, this process does not need to be repeated each semester.

3.3 Assigning permissions

The process of assigning permissions can be time-consuming. It involves initial setup and testing of user permissions, then subsequent maintenance each semester to purge old users from the previous semester, and adding new users for the current semester. There are capabilities within the Administration tool that allow copying of user permissions, but in most cases, manually creating each student account may be required before you can copy permissions.

A typical student user will not have administrative permissions. Each institution is encouraged to determine the Folder, State, and Transition permissions. Our course website <https://hub.wsu.edu/me-116/pdm/> has our current user permissions that can be reviewed and modified as needed. SWPDMS provides the ability to control state and transition permissions, this allows a grader to enter their comments and grades, and the student will not be able to change them once the grade has been finalized.

There are three main folders that we have in our IEG course. At the end of our IEG course, students work on a collaborative project together. Collaborative projects will require the creation of new project folders and providing specific access for team members to these folders. The main parent folders (Figure 5) contain the following:

- Course_Material- contains syllabus, presentations, videos, instructions, etc. (this can be reused from year to year if desired) (all students have access).
- Student_Submissions-SemesterCode- this contains a subfolder for each student, students can only view their folder (the SemesterCode allows organization if this folder moves to cold storage).
- Final_Projects_SemesterCode- this folder contains subfolders for each final (the SemesterCode allows organization if this folder moves to cold storage).

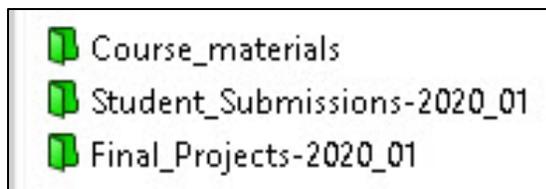


Figure 5. Folder structure for our IEG course

3.4 Markup tools & Student Feedback

Efficient feedback that is easily accessible to the students is our driving force to adopt SWPDMS. We utilize two tools that allow efficient feedback. The first is self-contained within SOLIDWORKS by adding comments to parts and assemblies. The second feedback system we use is eDrawings to provide markup on drawings.

The grading procedure for parts and assemblies follows this basic process:

1. Columns are organized to find all of the work that was assigned on a specific day.
2. Basic information is gathered, such as mass and volume; these values are compared to an answer key.
3. Correct files can be transitioned to the Final Grade state, and the score for each file is added to the metadata of that file.
4. Incorrect files are checked out, and the file is reviewed in SOLIDWORKS. Errors are determined, and the Comment tool within SOLIDWORKS is utilized.
5. When the file is checked back in, the grader can determine if they want the grade to be final by choosing the Passed Feedback Transition, or provide the student the opportunity to make changes by choosing the Editing Required Transition.
6. The student can open the file and review the comments that were placed into the file.

Below, Figure 6 captures typical comments that can be recorded within the software for student feedback.

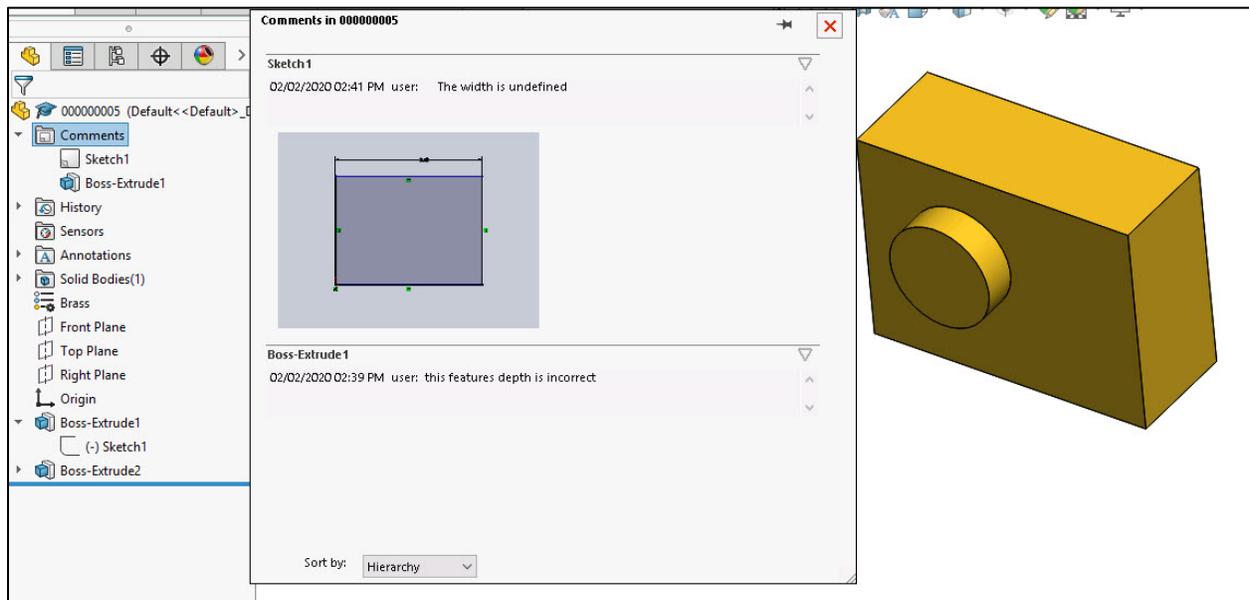


Figure 6. Student feedback recorded through the use of comments in a SOLIDWORKS file

The grading procedure for drawings is similar but uses eDrawings instead of SOLIDWORKS:

1. Columns are organized to find all of the drawings that were assigned on a specific day.
2. eDrawings is used to open the drawing file.
3. Comments are made, and then the eDrawing is saved back into the student's folder, for their review.
4. Correct drawings can be transitioned to the Final Grade state, and the score for each file is added to the metadata of that file.

5. The comments are stored in an eDrawing file, and the students can see exactly where they had issues on the drawing.
6. The grader can then determine if they want the grade to be final by choosing the Passed Feedback Transition, or provide the student the opportunity to make changes by choosing the Editing Required Transition.
7. The student can open the eDrawing file and review the comments that were placed into the file. Then they can make edits to their drawing and change the state to Needs grading.

Figure 7 captures typical comments that can be recorded within the eDrawing software for student feedback. The comments are placed exactly where the issue occurs and can be added with a keyboard and mouse or with a stylus, allowing easier virtual markup of drawings.

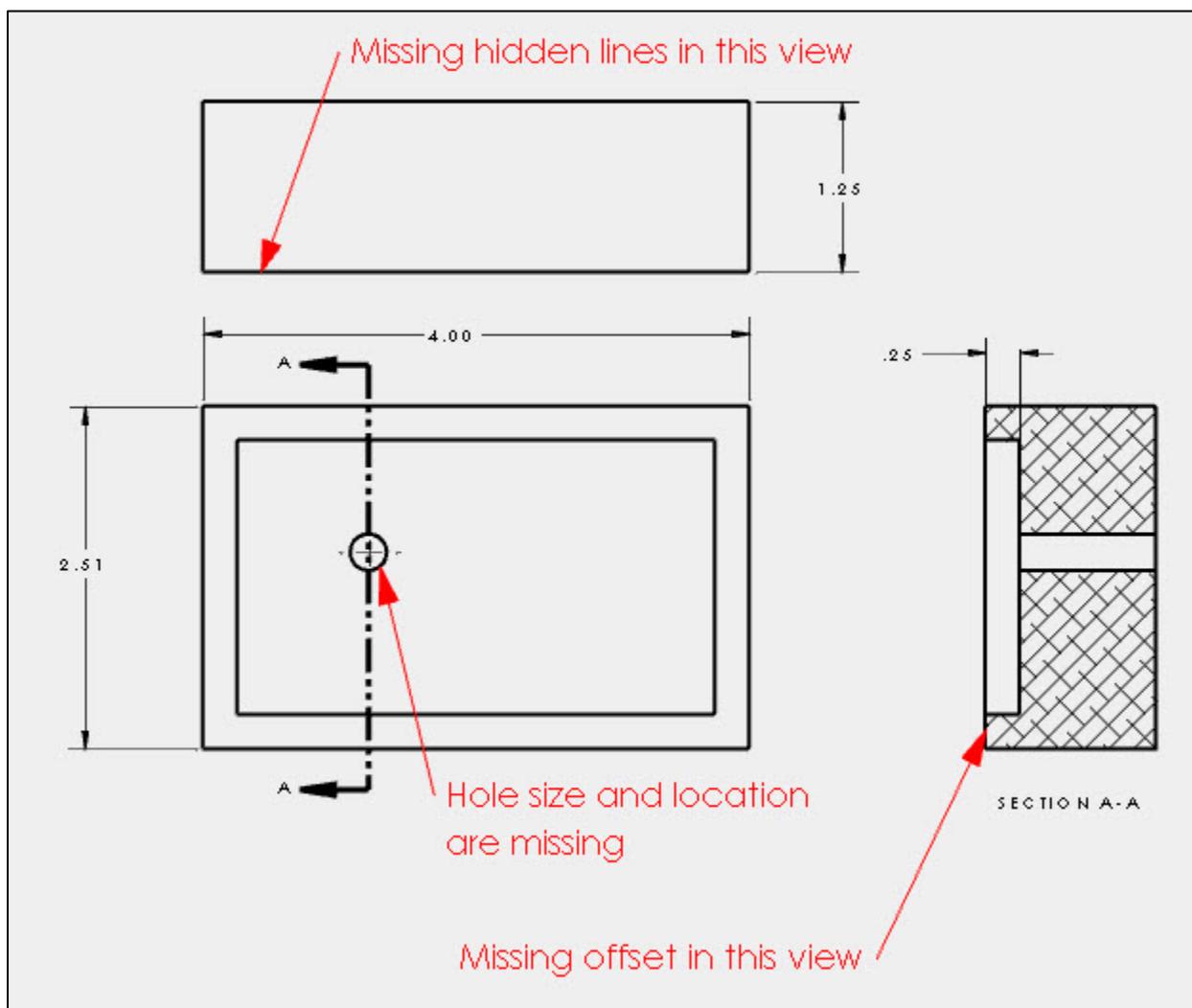


Figure 7. eDrawing feedback example

Through SWPDMS, students can utilize these workflows to get help on assignments before they are submitted, gain feedback typical of their future careers, and easily view and interpret that

feedback. No longer will they have to rely on comments posted into a non-CAD system, they will get the comments exactly where they need them, improving the impact of the feedback.

3.5 Metadata for further research

Each file contains metadata that is stored inside of a Microsoft SQL database. This information can be accessed by running an SQL query. The default installation of SWPDMS does not include all of the tools necessary for a query to be run. However, Medeiros (Data Mining) provides a solution to this problem, as well as example scripts that can be used to query the database.

The ability to track student performance on specific exercises semester over semester allows for educational research to occur over many semesters without having to perform significant data mining. The information will be associated with each file through custom properties, such as grade and grader comments, that the grader enters during the grading workflow. An instructor can look at results from the current semester and determine that some concepts did not score comparatively well. The instructor can then create a treatment for that particular concept for the next semester, and observe if there was an impact. Through the use of metadata and queries, educators can more efficiently utilize resources to address key problem areas.

4 Conclusion

Most industries have adopted some form of PDM to increase design efficiency. Educational institutions have had the opportunity for several years to implement a PDM system at low to no cost. Buchal states that utilizing PDM in a large class may be time-consuming. [7] Our initial implementation in an IEG has been discussed and is shared at our course website <https://hub.wsu.edu/me-116/pdm/> to promote further implementation across academic institutions and provide reasonable insight into implementation.

Our university will be sharing our implementation with a club shortly, and we also plan to utilize the data mining capabilities associated with SWPDMS in future educational research.

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