IDAHO DESIGN ENGINEERING ANALYSIS WORKS (IDEAWORKS): COMPUTING RESOURCES, KNOWLEDGE MANAGEMENT, AND DESIGN OPTIMIZATION FOR NEXT GENERATION VEHICLES

Final Report
KLK430
N08-09

National Institute for Advanced Transportation Technology

University of Idaho

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October 2008
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<td>In today’s rapidly changing world, state-of-the-art approaches to design and just-in-time methods for learning relevant tools, techniques, and technologies are in great demand. For many organizations, especially Universities, this problem is accentuated by a large annual turnover of those who participate in research and development. An approach to knowledge transfer that integrates physical, virtual, and human elements is likely to be most effective with a broad spectrum of learner/practitioners. This is the vision underlying the creation of the IDEAWorks Laboratory in Gauss Johnson 115. The work was made possible through funding from NIATT, Mechanical Engineering Department, and an Idaho Technology Innovation Grant by the Idaho State Board of Education. The laboratory contains twelve identical high-end computing stations with state-of-the-art CAD software. It is supported by a fairly extensive library of short, student authored videos related to key software functions as well as hands-on learning activities facilitated by a team of graduate students who are deeply involved in our college-wide capstone design course as well as outreach to regional industries.</td>
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1. PROBLEM DEFINITION

At the 2008 Detroit Auto Show, three out of four new automobile designs were created using Dassault System’s CATIA, a high-powered computer aided design (CAD) tool used by industry leaders and applied to such innovative projects as the Boeing 787 Dreamliner. CAD tools such as CATIA, as well as other powerful design and analysis software (ABAQUS, FLOMERICS, ProE, ALGOR, ANSYS), enable engineers to work collaboratively in the global workplace while realizing their creative potential. University engineering programs in the state of Idaho must teach the skills and fundamentals associated with these powerful CAD tools in order to produce graduates that can compete in the global marketplace. This project explored an innovative and sustainable method for developing and delivering CAD related curriculum materials that are accessible on a just-in-time (JIT) basis.

The Department of Mechanical Engineering at the University of Idaho has committed to building a studio environment for learning advanced computational design tools. Over the course of the past two years, the Mechanical Engineering Department and the National Institute for Advanced Transportation Technology (NIATT) have created a computational project laboratory called IDEAWorks that is equipped with high-end workstations and advanced CAD tools such as CATIA.

This project consisted of two complementary enhancements. (1) This project seeks to enrich the IDEAWorks studio with locally authored and locally sustainable multimedia instructional modules for solid modeling and engineering analysis in CATIA that are needed to produce innovative and competitive engineering graduates. The modules will be available on a just-in-time basis in order to support dynamic projects and rapidly evolving student learning methods. (2) The IDEAWorks laboratory will also be enhanced through hardware additions for distributing just-in-time material, facilitating interaction in the classroom and enabling collaboration with external experts.
2. METHODS

2.1 Laboratory Development

This project sought to significantly advance a new learner-centered computing laboratory (IDEAWorks) that is intended to support senior design projects, competition vehicle projects, and graduate research in transportation. In addition to being a state-of-the-art research environment and versatile instructional classroom for technical electives/summer short-courses, the lab was anticipated to be a magnet for recruiting undergraduate students, graduate students, and faculty. During the 2006 fall semester, the principal investigators on this project were granted oversight to GJ 115 that will become the home for the new laboratory. To make this a reality, substantial investment was made in computing hardware (new high-end PCs, flat screen monitors, large screen projection equipment), room utilities (power, internet, lighting), room finishing (wall surfaces, floor, windows), and workstation furnishings (collaboration-friendly work areas, ergonomic surfaces for keyboards & books, and moveable chairs). Early on, a rendered image of the laboratory concept was developed to leverage NIATT funds with those of the Mechanical Engineering Department, ME alumni, and industry partners such as the Boeing Company and Dessault Systems.

Figure 1: IDEAWorks concept.

It was our hope that this new laboratory will do for the engineering analysis of the Mechanical Engineering Department and the NIATT what the ME shop does for the manufacturing dimension of our Mechanical Engineering program. Our initial effort will be to identify advanced application software such as CATIA and ALGOR as well as other tools that add analytical sophistication in support of our research and academic missions. While a vision for this laboratory was necessary to gain financial support, the vision had to be translated into a...
tactical plan that could be implemented with existing human resources—faculty, staff, graduate students in Idaho Engineering Works, and undergraduate student leaders. This required room reconfiguration, actualization of learning friendly workstations, acquisition and installation of appropriate computing equipment and peripherals, and enhanced proficiency with state-of-the-art software. Spontaneous creativity of students, faculty, and staff resulted in the current lab environment pictured below. Detailed specifications for hardware/software as well as furniture/fixtures implemented in IDEAWorks are given in the Appendix.

![Completed IDEAWorks](image)

**Figure 2: Completed IDEAWorks.**

### 2.2 Video Production

Previous experience creating instructional videos for our junior level solid modeling course was used to guide the production of video resources for IDEAWorks. An underlying theme in this video series was designing and drawing parts for manufacturability, including attention to modern drawing standards. This initial development resulted in sixteen 10-15 minute screen captures with voice over. Videos progressed from toolbars and settings, to full-defined sketches, to features that mimic machine operations, to moveable assemblies, and ultimately to shop drawings. These were piloted with over 90 students during the 2007-08 academic year. The following specifications were set out for the next generation of video resources used in IDEAWorks.

- Lessons should be scoped to last between 5-7 minutes.
- Validate lesson designs with story boards (screen shots).
- Each lesson is intended to be a standalone module.
Include a title page in each lesson that runs for 3-5 secs.
Include an overview page for 5-8 secs that introduces lesson topics.
Add music to title and overview page to assist with volume adjustment.
Utilize the pan/zoom feature in Camtasia (for visibility of menus/workbenches).
Hover over tools/buttons for 1-2 sec before selecting them (helps orient user).
If possible, have a selectable table of contents and/or text inlays.
Include recap page at the end of each lesson.
Make sure to record lessons in a secluded place where no interruptions will occur.
Attempt to produce videos in a universal file format.

A six step method for video realization was refined and formalized to insure adequate and timely attention to video contents as well as formatting. This supports authorship by advanced undergraduate students with provisions for faculty and staff input. All of the steps can be implemented by an experienced software user in less than 10 hours.

STEP 1: Review Course Design
  - Review existing video library
  - Study review forms submitted by previous students
  - Re-group material for more completeness and consistency
  - Interview instructors and mentors to validate sequencing
  - Generate revised table of contents with titles and topics

STEP 2: Develop Lesson Outline
  - Inventory major topics featured in each lesson
  - Interview CAD instructors and mentors to better understand areas of difficulty
  - Select examples for demonstrating key concepts
  - Set goal for lesson duration

STEP 3: Design Storyboard
  - Create or acquire CAD entities for use in examples
  - Capture images associated with each segment in video
  - Sequence images for greatest impact on learner
  - Develop script to communicate key points
  - Summarize objectives at the beginning
  - Reiterate important lessons learned at end

STEP 4: Rehearse Delivery
  - Practice screen motions needed to create storyboard elements
  - Synchronize screen motions and script for smooth delivery
  - Time session to insure that it is not too long or short
STEP 5: Record Lesson
- Configure screen capture software (Camtasia)
- Configure audio equipment
- Minimize background noise
- Record from beginning to end until desired quality is achieved

STEP 6: Package for Use
- Create title and table of contents frames along with music
- Utilize zoom feature to reveal hard-to-see menus, buttons, and parts
- Create concluding frame
- Balance overall sound level
- Render video in MOV file format (supply plug-in for Macs)

2.3 Implementation of Video Resources

A special technical elective course (ME 421/521) was created for teaching principles and practices of CATIA. Videos were used to support pre-class preparation. They were embedded in a course webpage located at www.webs1.uidaho.edu/mindworks/catia.htm shown below. Videos were the subject of regular quizzes at the beginning of each class session. Models used in the videos were often used in class discussions that followed the quiz.
2.4 Assessment and Continuous Improvement

As part of the new CATIA course, plans were made to measure the quality of the instructional videos and to provide input for improving the next generation of videos. The desire to maintain a state of the art lab environment and produce high quality learning objects demanded that the assessment process be sustainable in terms of gathering and applying feedback as well as keeping up with future software releases.

The core of the continuous improvement is the classroom assessment process. At the conclusion of assigned activities that include a video component, selected students assess the video using the form in Figure 4. This is done by completing a learning object review form that is often a part of
course requirements. These forms ask students to comment on the purpose, structure, and insights on selected video features. To date, the most common suggestions provided by the students were to increase the volume of the audio, provide larger zoomed in views of buttons and menu selections, and increase the number of examples.

After the completion of each learning object review, the assessment forms will be triaged by the instructor or course mentor. The triage process will identify problems that require immediate attention and problems that can wait for the video to be updated in parallel with a software update. An example of a problem that requires immediate attention would be if the video was entirely inaudible or if it had a major instructional error. An example of a problem that can wait for regular update would be a suggestion to increase a font size or restatement of some wording. Often these problems can be addressed in the short term with a posted errata.

### 2.5 Management of Software

To provide the highest quality learning experience for students in IDEAWorks a software management policy was established. The goal was to support a high quality instructional environment that could support class-wide research and development activity. This consisted of the following points.

- provide access to all software from all machines (preferably through network licenses)
- publicly post allowable software list and track location of existing licenses
- approve software installation by committee and insist that this be done by trained designees
- supply tools for restoring software settings to standard configurations
- expect that all software additions are accompanied by creation of just-in-time (JIT) resources for software/design learning
- publicly disseminate video standards/development process for JIT resources
- make software tools available for use over an entire academic year
- review software suite against available budget and supply recommendations for next year's licensing to unit administrators (ME and NIATT) each Spring
LEARNING OBJECT REVIEW FORM

Learning Object: 

Reviewer: Date: 

1. Purpose of video

2. Outline of content (w/approximate length for each section)

3. Feedback to Authors/Editors

<table>
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<th>VIDEO FEATURE</th>
<th>INSIGHTS/RECOMMENDATIONS</th>
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Figure 4: Learning Object Review Form.
3. FINDINGS/RESULTS/DISCUSSION

3.1 Industry Collaboration

Summer 2008 internships with the Boeing Company served to expand our knowledge of three-dimensional solid modeling and create a more valuable learning environment for future offerings of our Advanced CAD technical elective course (ME421/521). A special project on the use of design tables was selected for an on-campus intern for dual benefit to summer interns at Boeing. This project addressed a need at Boeing’s facility in Fredrickson, WA and allowed us to create a CATIA catalog of our HAAS mill holders and cutters that can now be employed in machining simulation and verification. With the knowledge gained by this project, we planned a special homework assignment for the fall 2008 course offering of ME 421/521. Over the course of several semesters, we have an ultimate goal of using this assignment to create and maintain a full catalog of ME shop tooling, accessible for machining verification and use in special manufacturing projects. As a result of these efforts, our next generation ME 421/521 students should have even better preparedness for Boeing summer internships and employment. The CATIA work described in this report serves as a foundation for deeper collaboration between the Boeing Company and faculty/staff/students involved in design education at the University of Idaho.

3.2 CATIA Video Library

18 CATIA videos were created prior to the start of the fall 2008 semester. The videos incorporate lessons learned in two prior course implementations (without videos) as well as insights gained through Boeing internships during the summer of 2008. A brief description of each video follows.

- **User Interface** – Introduction, toolbar defaults, File/Edit menus, help file navigation
- **Settings** – Units, color schemes, basic defaults
- **Basic Sketcher** – Sketcher workbench, sketch entities, common constraints
- **Advanced Sketcher** – Construction lines, profile/spline, sketch chamfer/fillet, sketch mirror
- **Pads and Pockets** – Pad/Pocket a sketch, feature chamfer/fillet, viewpoint manipulation
- **Multi-Selection Solid and Sweep** – Add planes, sweep a profile, connect sketches
- **Shafts, Grooves, Circular Pattern** – Feature patterns, grooves/shafts from a sketch
- **Assembly Basics** – Assembly workbench, design tree, constraints, manipulate parts, explode
- **Assembly With Constraints** – Assemble a product from parts, constraint usage
- **Design Tables** – Create/update a table, use relations, add a table to a catalog
- **Drafting Basics** – Templates, layouts, add/delete views, line properties
- **Dimensioning Drawings** – Page layout, dimension tool, tolerances, datums, callouts
- **Assembly Views** – Exploded drawing, bill of materials, part identification
- **Design Tables** – Create catalogs of parts using pre-defined parameters
- **Model Based Definition** – Represent drawing features three-dimensionally
- **Rendering Basics** – Environments, lighting, cameras, material properties
- **Assembly-Style Animation** – Shuttles, tracks, track sequencing, sequence animation
- **Rotational Animation** – Use of joints, degrees of freedom, driving a joint, simulation

The instructional videos described above are part of weekly lab preparation for our ME421/521 course. Along with other course material, they can be accessed through our class website at [http://www.webs1.uidaho.edu/mindworks/catia.htm](http://www.webs1.uidaho.edu/mindworks/catia.htm). As a convenience for external users, we have also packaged the CATIA lesson DVD-ROMS with custom University of Idaho Mechanical Engineering graphics based on CATIA modeling by 2007-08 students.

*Figure 5: ME 421 DVD.*
3.3 Past Student Projects

The final third of the ME 421/521 class features team projects that explore new horizons in solid modeling capability. A variety of these are described below. These projects uncovered new CAD/CAM functionality which was incorporated in the latest video library.

**Howell V4:** A team of 8 students collaborated to transform a paper drawing package into a fully assembled 3D model of the Howell V4 engine designed by Jerry Howell. The final project contained rendered images of the full assembly as well as a video showing the machining, assembly, and operation of the finished engine.

![Howell V4 engine](image)

**Strutt Epicyclic Clock:** 6 students took a drawing package and modeled each individual part in CATIA. Using these parts, a rendered assembly was created and then animated to show the clock’s mechanisms in action and the processes used to cut the internally-toothed gears.

![Strutt Epicyclic Clock](image)
Gauss-Johnson 115 Room Rendering: The classroom that currently houses the University of Idaho’s CATIA computer lab was an old mechanical engineering classroom until a rendering of the room was created and brought attention to the possibilities that the room contained. That initial rendering helped the department secure funding for the 13 cutting-edge computers, new custom tile floor, and 42-inch lesson displays.
**Howell V-Twin:** Similar to the Howell V4 project, 6 students were brought together to transform a paper drawing package of a miniature V-Twin engine into a working 3D model. The project includes high-resolution rendered assemblies and several videos depicting the engine working as if it were actually built and assembled.

![Howell V-Twin Engine](image1.png)

**Administration Tower Clock:** During the summer of 2008, one student on an internship with the U of I took a Master’s thesis from 1914 that illustrated how the University of Idaho’s Administration building clock could be built and built the parts in CATIA. This project was one of the first opportunities to explore the SolidWorks-CATIA interoperability as the gears for the project were built using GearTrax, a plug-in for SolidWorks and then transferred to CATIA with the use of the .STEP file format. The project culminated in a fully rendered assembly of the old workings of the Administration Building clock.

![Administration Tower Clock](image2.png)
Howell V4 Supercharger: With the Howell V4 engine project completed, the UI Mechanical Engineering department began looking into ways to further the Machine Shop’s technical capabilities. This project’s goal was to create a scale supercharger that could be fabricated and added to the Howell V4 after completion. A 4-lobe rotor design was chosen, and 3 students designed, drafted, assembled, and rendered the project which included modifying as few existing Howell parts as possible.

3.4 Current Student Projects

International Design Project: This project brings together 25 students from separate countries so that they could work in partnership to design a common device. This project included schools from France, India, Spain, and the United States. It introduced students to global design while performing a case study on the issues of global collaboration that are facing industry today. This semester’s project was an international formula car and included eight separate teams. Each team designed and modeled a sub assembly for the car. This project also identified communication needs in international model based design. Even though the language differences were a huge road block to get the project started, once the designers were developing prototypes they settled on the universal language of 3D communication. This study shows the international struggle that faces most of industry today and produced a need for further development of communication tools. We hope to take what we have learned from this project and continue to create international design projects that better educate our engineers at the University of Idaho.
**3D Machine Plan:** This project is based on the idea of a machining plan but takes it one step further with the use of 3DXML files. In this project, we are writing our own standards for a machine plan, but are using 3D files which mean that instead of having a screen shot of the machine setups and tool zeros, the document will have 3DXML files so that the part can be looked at and rotated. We are also performing a case study on the University of Idaho 2008-2009 Formula SAE car. A few parts are picked out that need machined for the car and are then developed with a 3D machine plan. The plans are then turned over to a machinist so that they may evaluate this type of 3D communication. These 3D machine plans can improve shop productivity. We hope to use this type of communication for our shop in the future at the University of Idaho.

**3D Assembly Manual:** This is a case study on the use of 3DXML files in an assembly manual. This is a case study of a barbeque that has paper assembly documents. We will buy the BBQ, draw it in CATIA, and then develop a PDF file that has 3DXML files in it that can be looked at and rotated. Imagine getting a BBQ at the store, popping a CD in a computer and looking at files that can be manipulated, instead of being confronted by pages of 2D drawings. We can make assembly documents more clear with 3D communication. If this works, it is possible to imagine missile silo assembly instructions in 3D, or a truck bed manufacturer having welding instructions for his welders in 3D.

**Part Family Machining:** This is a case study on the NC workbench and the ability to create an NC code for a family of parts. First we created the NC code for a part and then inserted a similar part and had CATIA automatically find the surfaces for the tool paths to attach. This could be helpful in an industrial setting when many parts are being machined with minor differences.
4. CONCLUSIONS/RECOMMENDATIONS

The enhancements to the IDEAWorks laboratory described in this report enhance an existing, innovative approach to teaching and learning, benefiting the entire learning community of undergraduate students, graduate mentors, faculty, external consultants, and industry partners. Increasing student capabilities is dependent on improving and customizing learning for the multitude of different CAD/CAM projects that will be supported by this lab. In a project-driven course, students are motivated to grow their understanding of the subject matter and improve their skills in order to progress on their individual project. Instruction on a predefined schedule often does not convey the appropriate material at the appropriate time. However, JIT learning modules provide the needed educational tools on demand, thereby extending the instructional reach of mentors and faculty associated with different aspects of design education at the University of Idaho.
APPENDIX A: COMPUTER HARDWARE/SOFTWARE IMPLEMENTED IN IDEAWORKS

HARDWARE
- 13 Custom-built tower desktops
  - Intel Core 2 Duo Processor (3.0GHz)
  - 4GB RAM
  - NVIDIA GForce 8600 Video Card
  - 370GB HDD
  - Windows XP Professional
    - CATIA V5 R17/18
    - SolidWorks 2008 SP4.0
    - Microsoft Office 2007
    - VERICUT 6.2
    - Abaqus 6.7
    - Mozilla Firefox 2.0
- Logitech LX310 Cordless Desktop Keyboard and Mouse
- ViewSonic VG2230wm 22-inch Monitors

SOFTWARE
- Printer connected through network
- T-Drive (no password)
- CATIA V5 R17/18
- SolidWorks 2008 SP4
- Firefox 2.0 (if possible)
- Vericut 6.2
- MS Office 2007
- Dassault Systemes 3D XML viewer
- Adobe Acrobat 9
- Adobe Photoshop CS3 (preferred)
- Abaqus 6.7
- Latest video card drivers
- Logitech Keyboard/Mouse software

42” LCD Projection Screens BOM
- ViewSonic CD4620 monitor
- 25’ HDMI cable
- HDMI Splitter box
- DVI to HDMI cable (6’)

Idaho Design Engineering Analysis Works (IDEAWorks) . . .