AC 2011-1557: ONLINE INSTRUCTIONAL MATERIALS IN A HYBRID INTRODUCTORY ENGINEERING GRAPHICS COURSE: AN INVENTORY OF SOLID MODELING CONCEPTS

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Online Instructional Materials in a Hybrid Introductory Engineering Graphics Course: An Inventory of Solid Modeling Concepts

Abstract

This paper reports on the continuing work on assessing the design and instructional effectiveness of a hybrid (mixed online and face-to-face) introductory engineering graphics course. Specifically, this paper examines the alignment of online and textbook-based instructional resources supporting constraint-based solid modeling—a core component of this course. An inventory is conducted of the key concepts in the online video resources supporting solid modeling concept instruction. The order and completeness of the inventory is compared with what is presented in the required textbook. A primary goal is to provide a mechanism for reviewing how our original instructional goals for learning constraint-based solid modeling is or is not being supported as we move course resources online. To that end, is higher order understanding of how constraint-based solid modelers work, and how one strategizes about part and assembly construction with appropriate design intent, being adequately supported? The results of this inventory is used to generate implications for future work in developing the course.

Introduction

A hybrid version of GC120-Foundations of Graphics has been offered by the faculty in the STEM Education department at NC State University since the Fall 2007 semester. Originally the course had two face-to-face meetings per week. The revised course now has one face-to-face meeting, and students are expected to complete additional online material outside of class. The online materials consist of streaming media of voiced-over lectures, online assessments of the textbook material, solid modeling demonstrations, and sketching videos. Previous studies suggest that students had multiple strategies for making use of these online resources, and that these strategies had implications for learning outcomes on summative measures in the course [1-5].

The next progression in evaluating the effectiveness of the course is to examine the resources supporting the solid modeling component of the course. When faculty first introduced constraint-based solid modeling into the course ten years ago, key concepts were identified and outlined for all instructors to follow. Since demonstrations were only conducted in a face-to-face setting, capturing what was actually presented to students across all sections of the course by different instructors was difficult. By placing the instructional resources online within a learning management system (LMS), what resources are now available to all students in the course is now verifiable. It is now possible to conduct a more thorough evaluation of the resources supporting solid modeling by examining the concepts presented in the online materials (i.e., video demonstrations) and compare them with those presented in the required textbook for the course.

The textbook for course, Fundamentals of Graphics Communication[6], in principle contains all of the core concepts taught in the course. Historically, these concepts have been divided between more abstract concepts supported exclusively through lecture and concepts that could be translated into more “hands-on” lab-based activities. These later concepts primarily focus on the use and application of constraint-based solid modeling. These concepts include setting up template files, applying sketch relations (e.g., symmetric, tangent, horizontal, vertical, and collinear), adding dimensional constraints to sketches, applying end-conditions to features (e.g.,

blind, through-all, or up-to-next), patterning features, creating assemblies, and creating drawings. The inclusion of these topical concepts in the course have evolved through a combination of top-down (introduction because they were in the textbook) and bottom-up (this is what the software includes in its feature set) decision-making. These concepts, in theory, are to be supported by a combination of online video demonstrations, textbook readings, and voiced-over slide videos supporting the textbook. What has not been fully explored by the course is the mapping of lab activities—and the underlying concepts required to successfully complete the lab—and the supporting textbook and video demonstration resources. Key questions to be answered are:

- What is the alignment between the concepts presented in the videos and textbook?
- Is the sequencing of the concepts appropriate?
- Is there appropriate scaffolding of the concepts over the progression of the semester?

Solid Modeling Concepts

Constraint-based solid modeling has been an integral, required part of GC120 since the spring 2001 semester. Faculty have continued to make improvements to the solid modeling tutorials over the last 9 years, which initially consisted of printed handouts. In 2002 handouts were replaced with web pages with screen captures of key steps in the assignment. Streaming video demonstrations replaced these static web pages in 2007. Although faculty have informally identified key concepts that need to be covered in the course based on textbook concepts and industry practice, a formal inventory of concepts has not yet been completed. Similarly, such a detailed inventory has not been identified in the published literature. For example, Hartman[7] looked at the CAD curriculum, but only in relation with regards to what topical concepts concerning surface modeling might be added to a typical CAD course. Bertozzi and colleagues[8] looked at a three-semester course sequence, but with that scope were only able to provide a coarse-grained overview of the concepts covered (including many that were not specifically about constraint-based modeling).

While some may consider these “skills” rather than “concepts,” because these ideas are independent of a particular software package and require higher-level conceptual understanding and strategic application of what makes a constraint-based solid-modeling tool function, we still consider these concepts. Because of this definition, we separate those skills/concepts specific to the SolidWorks software package from the more general concepts. To begin this process, the researchers examined the 17 videos that directly support instruction in the course. These videos are a core component of the course and students are expected to use them to complete required assignments. The videos are listed in Table 1. Since the content of the first video (Overview of SolidWorks) was covered in the face-to-face section of the class, Moodle data was not available for analysis. Next, an inventory of the concepts was completed, which included explicit concepts that were explained and demonstrated as well as implicit concepts that were just performed. After an initial list was compiled and refined by the researchers, eighty concepts were identified and categorized. Table 2 displays the list of concepts by modeling categories.

Table 1. Solid Modeling Videos.

Number	Video Name
1	Overview of SolidWorks
2	Copying SolidWorks Template Files
3	Creating a simple rectangular prism
4	Creating object 93
5	Modeling the ANGLE BRACKET
6	Modeling the ROD GUIDE
7	Modeling the HINGED CATCH
8	Creating a drawing of the HINGED CATCH
9	Modeling the PISTON CAP
10	Modeling the STOP BASE
11	Creating a drawing of the STOP BASE
12	Modeling the ARBOR SUPPORT
13	Creating a drawing of the ARBOR SUPPORT
14	Modeling and creating a drawing of the CENTER SUPPORT
15	Modeling and creating a drawing of the LONG SUPPORT
16	Creating the CLAMP Assembly
17	Creating an exploded view of the CLAMP Assembly

Table 2. Concepts Covered in the Solid Modeling Videos.

Concepts Addressed in the Solid Modeling Videos	Number of Concepts Per Concept Category
SolidWorks Specific Concepts	4
Modeling General Concepts	3
Sketch	15
Relations	10
Features	11
Dimensions	16
Assembly	4
Mates	5
Drawing	9
View	3
TOTAL	**80**

In addition to the concepts covered in the demonstration videos, an analysis was made of the concepts covered in the required textbook[6] for the course (Table 3). To assess coverage (e.g., concepts in the textbook not covered in the videos), the textbook concepts were compared to the concepts covered in the videos (Table 4). The reverse of the coverage analysis in Table 3, what concepts were covered in the video that were not covered to some degree in the textbook, was

conducted. This analysis revealed that the first concept category in Table 2 (SolidWorks Specific Concepts) was the only category not touched on in the textbook at all. In addition, some software-specific demonstrations of geometry creation and drawing notation were also not represented directly in the text. Table 5 provides a more detailed explanation of the concept categories and the mapping between video demonstration concept categories and textbook sections.

Table 3. Textbook Sections Containing Material from the SolidWorks™ Videos.

Section Number	Section Name
3.8	Constraining Profile Geometry for 3-D Modeling
4.4	Model Planning
4.5	Feature Definition
4.5.1	Features from Generalized Sweeps
4.5.2	Construction Geometry
4.5.3	Sketching the Profile
4.5.4	Completing the Feature Definition
4.5.5	Feature Planning Strategies
4.6.2	Editing Feature Properties
4.7	Duplicating Part Features
4.8	Viewing the Part Model
4.8.1	View Camera Operation
5.1	Projection Theory
5.2	Multiview Projection Planes
5.4	The Six Principal Views
5.5	Mulitview Sketching
5.6	View Selection
6.1	Auxiliary View Projection Theory
6.2	Auxiliary View Classifications
8.1	Sectioning Basics
8.2	Cutting Plane Lines
8.3	Section Line Practices
8.4.1	Full Sections
9.1	Dimensioning
9.3	Detail Dimensioning
9.4	Dimensioning Technique
11.1	Assembly Modeling
11.3	Working Drawings
11.3.2	Assembly Drawings
11.3.5	Title Blocks
11.3.10	Scale Specifications
11.4	Standard Parts

Table 4. Concepts Covered in the Required Textbook.

Concepts Addressed in Textbook	Number of times Video addresses Textbook Concept
Feature	12
Associativity (bidirectional and unidirectional)	4
Constraints	24
Design Intent	33
Equal Radius	2
Equal Length	1
Base Feature	6
Sweeping operations	9
Profile	11
Path	6
Construction geometry	8
World coordinate system	3
Sketch plane	4
Relative coordinate system	8
Methods for defining construction planes	2
Profile sketch	11
Open and closed loops	3
Thin features	0
Linear sweep (extrude)	4
Circular sweep (revolve)	3
Path-based sweep	1
Blend sweep (loft)	0
Feature end conditions	3
Non-sketch based features (holes, bosses, fillets, etc.)	3
Feature planning strategies	5
Editing features	1
Feature order	0
Feature tree	0
Parent-child relationships	0
Duplicating features	2
Linear array	0
Radial array	1
Mirror	5
Viewing options	7
Viewing models from different directions	0

Table 5. Detailed mapping of concepts between video concept category and textbook sections

Concept Category	Concepts	Textbook Sections
SolidWorks General Concepts	Selecting a surface, changing the material, sketching on a newly created reference plane, setting up template files	4.5.2, 11.3 Construction Geometry Working Drawings
Modeling General Concepts	Planning part orientation, feature end conditions, selecting default workplanes	4.4, 4.5.2, 4.5.4, 4.8, 5.4 Model Planning Construction Geometry Completing the Feature Definition Viewing the Part Model The Six Principal Views
Sketch	Creating the following: centered rectangle, line, center line, circle, new sketch, sketch fillet, construction circle. Fully defining sketches. Converting entities. Geometry to define a reference plane. Hole Wizard sketches.	3.8, 4.4, 4.5.1, 4.5.2, 4.5.3, 4.5.5 Constraining Profile Geometry Model Planning Features from Generalized Sweeps Construction Geometry Sketching the Profile Feature Planning Strategies
Relations	Adding the following relations: vertical, horizontal, coincident, midpoint, symmetric, collinear, equal, tangent, parallel, concentric	3.8, 4.5.2 Constraining Profile Geometry Construction Geometry
Features	Extruded boss-base, cut-extrude, revolved boss-base, revolved cut, changing extrude distance, midplane extrude, up-to-next extrude, fillet, circular pattern, reference plane, Hole Wizard	3.8, 4.5.1, 4.5.2, 4.5.4, 4.6.2, 4.7, 11.4 Constraining Profile Geometry Features from Generalized Sweeps Construction Geometry Completing the Feature Definition Editing Feature Properties Duplicating Part Features Standard Parts
Dimensions	Smart Dimension: length of line; distance between arcs or circles; diameter; distance between lines; angle between lines; radius; distance between line and arc. Adding a note. Adding a diameter to a revolved sketch. Changing the properties to MAX or MIN. Insert-Model Items. Adding dimensions to a drawing. Modifying extension lines. Moving dimensions. Removing parentheses from reference dimensions. Rotating center marks.	3.8, 9.1, 9.3, 9.4 Constraining Profile Geometry Dimensioning Detail Dimensioning Dimensioning Technique
Assembly	Order of files in an assembly. Adding new parts to an assembly. Exploded views. Moving parts in an exploded view.	11.1, 11.3.2 Assembly Modeling Assembly Drawings
Mates	Coincident, distance, concentric and parallel mates. Adding mates between default planes.	11.1 Assembly Modeling

Drawings	Adding a model view. Adding projected views. Adding center lines. Changing information in the title block. Changing the drawing scale. Adding center marks. Changing the size of center marks. Adding a primary auxiliary view. Creating a full sectional view.	5.1, 5.2, 5.4. 5.5, 5.6, 6.1, 6.2, 8.1, 8.2, 8.3, 8.4.1, 11.3.10 Projection Theory Multiview Projection Planes The Six Principal Views Multiview Sketching View Selection Auxiliary View Projection Auxiliary View Classifications Sectioning Basics Cutting Plane Lines Section Line Practices Full Sections Scale Specifications
View	Tangent edge removal, turning off temporary axes and origins, adding hidden lines to a drawing.	4.8.1, 5.5 View Camera Operations Multiview Sketching

To address the appropriate scaffolding of the concepts, a table was created (Table 6) listing the measurable concepts in the videos and indicating whether they were present in a particular video. This method of presenting the data shows how many times individual concepts are presented during the semester and helps faculty see where gaps may exist for reinforcing the concepts.

Table 6. Scaffolding of Concepts over the Tutorials.

Category	Concept	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Tools-Options	Use Tools-Options-File Locations	■																
Sketch	Creating a centered rectangle.		■				■											
Feature	Creating an extruded boss-base feature.		■	■	■	■	■	■			■					■		
Feature	Creating a cut-extrude feature.		■			■	■	■					■					
Design Intent	Distinguish between Through-All and Blind end conditions.		■	■			■	■			■		■					
Workplane	Selecting a default workplane / construction plane.		■	■	■	■	■	■			■					■		
Sketch	Creating a center line.		■															
Relations	Adding a Vertical relation.		■			■					■		■					
Relations	Adding a Horizontal relation.		■										■			■		
Relations	Adding a Coincident relation.		■		■						■							
Relations	Adding a Midpoint relation.		■	■				■										
Relations	Adding a Symmetric relation.		■													■		
Dimension	Smart Dimension - length of a line.		■	■														
Dimension	Smart Dimension - distance between two arcs or circles.		■		■	■							■					
Dimension	Smart Dimension - diameter of a circle.		■	■	■		■	■			■		■			■		
Dimension	Smart Dimension - distance between lines.			■	■		■	■			■					■		
Feature	Changing the distance of an extrusion.		■															
SW General	Selecting a surface.		■			■	■	■			■							
Sketch	Creating a circle.		■	■		■	■	■					■			■		
Sketch	Creating a line.			■	■	■	■	■					■			■		
Relations	Adding a Collinear relation.			■				■								■		
Relations	Adding an Equal relation.			■		■		■					■			■		
Sketch	Creating a new sketch.			■														
Relations	Adding a Tangent relation.				■	■	■											
Relations	Adding a Parallel relation.				■													
Dimension	Smart Dimension - angle between two lines.				■								■					
Dimension	Smart Dimension - radius of an arc.				■		■						■			■		
Sketch	Adding a center line to help constrain geometry.				■													

Dimension	Adding a note in front of a dimension.																	
Dimension	Smart Dimension - distance between a line and an arc.																	
Sketch	Fully defined sketch - Black geometry is fully constrained.																	
Relations	Adding a Concentric relation.																	
Feature	Creating a Midplane end condition.																	
Sketch	Adding a center line through the Origin.																	
Sketch	Adding a sketch fillet.																	
Feature	Adding a Fillet feature.																	
SW General	Changing the SolidWorks material.																	
Drawing	Add a model view.																	
Drawing	Add projected views.																	
View	Tangent Edges Removed.																	
View	Turn off Origins and Temporary Axes.																	
View	Add hidden lines to a drawing view.																	
Drawing	Add center lines to a drawing view.																	
Drawing	Edit the information in the titleblock.																	
Drawing	Changing the drawing scale of a view.																	
Drawing	Changing the size of center marks.																	
Feature	Create a revolved boss-base feature.																	
Feature	Create a circular pattern.																	
Dimension	Adding a diameter dimension to a revolved sketch.																	
Sketch	Making geometry "For Construction".																	
Sketch	Convert Entities.																	
Feature	Creating an Up-to-next end condition.																	
Dimension	Changing the properties of an arc to go to the Max or the MIN.																	
Modeling General	Planning the Orientation of the part.																	
Dimension	Insert-Model Items-Dimensions.																	
Dimension	Add new dimensions to a drawing view.																	
Drawing	Adding center marks.																	
Dimension	Changing the length of extension lines to leave a visible gap.																	
Dimension	Moving dimensions.																	

Dimension	Removing the parentheses from driven or reference dimensions.																	
Sketch	Add necessary geometry to create a reference plane.																	
Feature	Add a reference plane - Insert - Reference Geometry Plane.																	
Sketch	Creating a sketch with only reference geometry.																	
SW General	Sketching on a newly created reference plane.																	
Drawing	Add a primary auxiliary view.																	
Dimension	Rotating a center mark.																	
Drawing	Create a full sectional view - View Layout-Sectional View.																	
Sketch	Create a construction circle (bolt circle) for locating circles.																	
Feature	Creating a revolved-cut feature.																	
Feature	Hole Wizard for creating counterbores.																	
Sketch	Locating holes with the Hole Wizard sketch view.																	
Assembly	The order files should be added to an assembly.																	
Assembly	Insert-Components to add new parts to an assembly.																	
Mates	Mates - Coincident.																	
Mates	Mates - Distance.																	
Mates	Mates - Concentric.																	
Mates	Mates - Parallel.																	
Mates	Adding mates between default planes.																	
Assembly	Insert - Exploded View.																	
Assembly	Moving parts in an exploded view.																	

Summary

This paper has provided a useful example of a how a systematic analysis of curriculum-to textbook-to video tutorial mapping can reveal how, if at all, key concepts in the curriculum are being supported by textbook readings, video tutorial demonstrations, both, or neither. In addition, how these concepts are presented and reinforced over time in the course, provides some sense as to whether an appropriate level of scaffolding and reinforcement is being provided. As one would expect, the textbook concepts tend to be general enough to apply to any constraint-based computer-aided design program. That is, the textbook attempts to focus as a higher level than specific commands to manipulate software and instead focus on general concepts of constraint-based modeling. In contrast, although some of the concepts covered in the online video demonstrations are general enough to apply to other programs, most are specific to SolidWorks™. That is, the videos provide concrete demonstration of the concepts presented in the textbook along with software-specific instructions not relevant for textbook presentation. The mapping of concepts over the weeks of the semester revealed that a block of core concepts were presented early and repeated over the course of a few weeks along with, at times scatter reinforcement in later weeks. Later, more advanced concepts, tended to be introduced once and not reinforced. Follow-on research will investigate more the learning implications behind the distribution of instructional support of the key concepts identified in this analysis.

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