Online Solid Modeling Resources in a Hybrid Introductory Engineering Graphics Course: An Inventory and Assessment of Solid Modeling Concepts

***Mark A. Shreve*[1], *Theodore J. Branoff*[2] & *Eric N. Wiebe*[3]**

Abstract – This study looks at evaluating the effectiveness of moving an introductory engineering graphics course from a face-to-face to a hybrid format, examining the online resources related to solid modeling instruction used in an introductory engineering graphics course at North Carolina State University. Online video demonstrations were placed within a learning management system (LMS) so that faculty could more accurately determine how students were using the resources. An inventory of modeling concepts covered in the videos was completed and compared with those presented in the required textbook for the course. Selected student modeling exercises were evaluated for near and far learning transfer of the concepts for two sections of the course. The collected data suggests that students' performance on solid modeling activities was not noticeably affected by whether or not the student watched the solid modeling video demonstrations.

Keywords: constraint-based solid modeling, engineering graphics, hybrid instruction, learning transfer.

INTRODUCTION

Over the past 3 years, faculty in the Technology, Engineering and Design program at North Carolina State University have been examining the effectiveness of hybrid instruction in their introductory engineering graphics course: GC 120 – Foundations of Graphics. Approximately 350 students are enrolled in this course per semester. A majority of the students are completing their second year of coursework in engineering. Previous studies involving this course suggest that students had multiple strategies for making use of the online resources related to asynchronous video lectures, and that these strategies had implications for learning outcomes on summative measures in the course [2-5, 9]. Researchers from outside engineering graphics have found that students perceive benefits from the incorporation of video demonstrations into courses in science [7]. Also, other researchers call for more formal evaluation of the value of multimedia in student learning environments [8].

The next progression in evaluating the effectiveness of the course is to examine the resources supporting solid modeling. When faculty first introduced constraint-based solid modeling into the course, 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 happening across all sections of the course by different instructors was difficult. By placing the instructional resources online within the Moodle™ LMS (i.e., video demonstrations), a more accurate picture of student use is available. 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 (see Figure 1) and compare them with those presented in the required textbook for the course.

While consistency of delivery across sections is now achieved through the use of videos, there is still the question as to the effectiveness of the delivery method. The researchers are studying the efficiency of knowledge transfer between concepts presented within the online video solid modeling demonstrations and submitted student work. Transfer of knowledge or learning has been an interest for educators and cognitive scientists for quite some time. Two issues are common regarding transfer. First, students either lack the motivation to engage and learn or their learning environment was not adequate for them to acquire sufficient knowledge. The second issue is that students do not always discern the connections between previous knowledge and new contexts [6].

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[1] North Carolina State University, Raleigh, NC 27695-7801, mashreve@ncsu.edu

[2] North Carolina State University, Raleigh, NC 27695-7801, ted_branoff@ncsu.edu

[3] North Carolina State University, Raleigh, NC 27695-7801, eric_wiebe@ncsu.edu

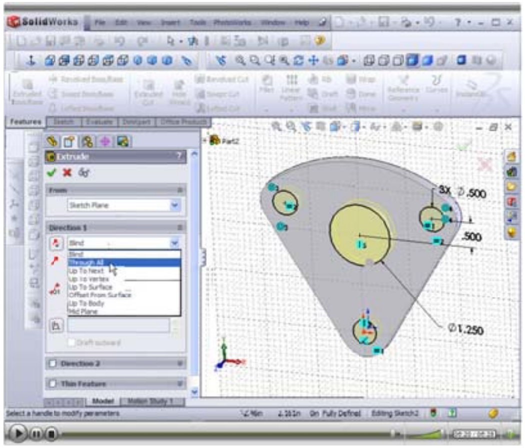

Figure 1. Screen Capture of a Solid Modeling Video Demonstration.

For this current work, two definitions related to transfer of learning are important. ***Near transfer*** of knowledge occurs when the activity or learning situation closely resembles the original activity or situation. ***Far transfer*** occurs when a student's knowledge is applied to an activity or situation that varies from the initial activity [6]. In the hybrid GC120 course, students were asked to complete two assignments in each of the weekly units. The first assignment was to replicate what was presented in the video demonstration for the unit (near transfer). For the second assignment, students were asked to complete an activity that was similar to the first assignment but with no help from a tutorial (far transfer).

SOLID MODELING CONCEPTS

Constraint-based solid modeling has been an integral 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. Steaming 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.

To begin this process, the researchers examined the 18 videos that directly support instruction in the course. 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. The list of concepts by modeling categories appears in Table 1.

Table 1. Concepts Covered in the Solid Modeling Videos.

Concepts Addressed in the Solid Modeling Videos	Number of Concepts Per Concept Category
SolidWorks General Concepts	7
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 for the course [1]. The textbook concepts were then compared to the concepts covered in the videos (Table 2).

Table 2. Concepts Covered in the Required Textbook.

Concepts Addressed in Textbook	Number of Concepts from Video that address Textbook Material
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

As one would expect, the textbook concepts tend to be general enough to apply to any constraint-based computer-aided design program. Although some of the concepts covered in the online video demonstrations are general enough to apply to other programs, most are specific to SolidWorks™.

METHODOLOGY

For this research, data were collected from two sections of GC120 taught by one instructor during the Fall 2010 semester. All online materials for the course were available only through the Moodle™ LMS. The participants' demographic data appear in Tables 3-5.

Table 3. Enrollment Per Hybrid Section of GC120.

Section	Frequency	Percent
001	30	52%
005	28	48%
TOTAL	58	100%

Table 4. Academic Year.

Year	Frequency	Percent
Freshmen	7	12%
Sophomore	35	60%
Junior	8	14%
Senior	8	14%
TOTAL	58	100%

Table 5. Academic Major.

Major	Frequency	Percent
Agriculture & Life Sciences	5	8%
Civil Engineering / Construction Management	8	14%
Computer Science	4	7%
Mechanical Engineering	18	31%
Other Engineering Majors	15	26%
Education	4	7%
Other Majors	4	7%
TOTAL	58	100%

There were 58 students initially enrolled in the two hybrid sections of the course. Sixty percent of the students were sophomores since GC120 is taken in the sophomore year for many engineering majors. Seventy-one percent of the students were engineering majors with the largest proportion being from mechanical and civil engineering.

As in previous semesters, students were required to view and complete online materials each week. These materials were organized into 12 weekly online units. Each unit consisted of streaming media presentations of the textbook material, streaming media SolidWorks™ demonstrations, and streaming media sketching demonstrations. Students also were required to complete a 10-20 question online assessment in Units 1-5 and 8-11 as a check of their textbook knowledge. Each assessment was paired with a streaming video of a voiced-over PowerPoint™ presentation of the key concepts of the required textbook readings for the week. Each unit also had at least one SolidWorks™ video demonstration. Students were typically asked to complete the activity demonstrated in the video as well as another activity that was similar. Of interest in this study was how students performed on both of these assignments with the purpose of examining near and far transfer of the concept learning.

Since all of these materials were placed within Moodle™, the researchers could track how students progressed through the materials. Of particular interest in this study was how students made use of the online materials related to the solid modeling demonstrations. Students were given access to 18 solid modeling video demonstrations in the units. Table 6 shows the number of videos watched by students in the two sections.

Table 6. Number of Solid Modeling Videos Watched.

Videos Watched	Frequency	Percent
18	3	5%
17	7	13%
16	4	7%
15	3	5 %
14	9	16%
13	7	13%
12	9	16%
11	7	13%
10	2	4%
9	4	7%
8	1	2%
TOTAL	56	100%

For this preliminary evaluation of the solid modeling concepts, one near transfer and two far transfer activities were selected. The near transfer activity was the ROD GUIDE (Figure 2), and its paired far transfer activity was the EYELET (Figure 3). The second far transfer activity was the TAPER COLLAR (Figure 4). This activity was given in Unit 10 and consisted of a solid model and a drawing.

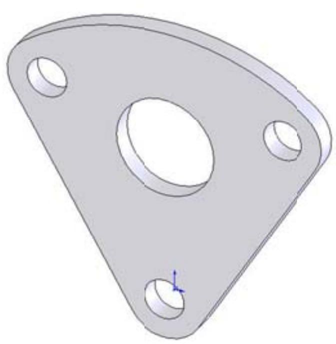

Figure 2. The ROD GUIDE model.

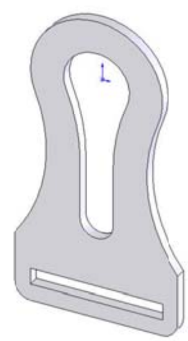

Figure 3. The EYELET model.

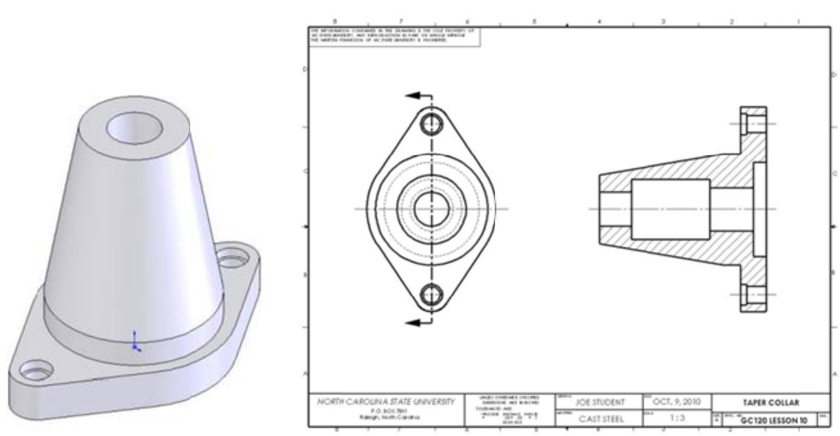

Figure 4. The TAPER COLLAR Model and Drawing.

Results

Concepts for each assignment were reviewed to determine which could be easily identified and measured within each student's solid modeling file. There were 13 measureable concepts identified for the ROD GUIDE model, 19 for the EYELET model, and 21 for the TAPER COLLAR model and drawing. Once the concepts were outlined, all three activities were assessed for the presence of each identified concept. Tables 7-9 show the results for the three assignments.

Table 7. Analysis of ROD GUIDE Assignment.

	Frequency	Percent	Average # of Concepts
Watched RG Video	36	67%	11.47
Did Not Watch	18	33%	10.50
TOTAL	54	100%	

Table 8. Analysis of EYELET Assignment.

	Frequency	Percent	Average # of Concepts
Watched RG Video	36	67%	18.00
Did Not Watch	18	33%	17.90
TOTAL	54	100%	

Table 9. Analysis of TAPER COLLAR Assignment.

Videos Watched Prior to Assignment	Frequency	Percent	Average # of Concepts
12-13	15	29%	14.20
10-11	21	42%	15.00
6-9	15	29%	14.30
TOTAL	51	100%	

For the near transfer ROD GUIDE solid modeling activity, 36 students watched the video before or as they were modeling the part. The average number of concepts present for these students was 11.47 out of the 13 measureable concepts identified for the assignment. The average number of concepts present for students who did not watch the video was 10.50. The EYELET was the far transfer activity for the ROD GUIDE video. For students who watched the ROD GUIDE video, the average number of concepts present in their files was 18.00 out of the 19 measureable concepts. The average for students who did not watch the video was 17.90. The last assignment evaluated was the TAPER COLLAR. As shown in Figure 4, this consisted of a solid model and a drawing. There were 21 measureable concepts identified for this assignment. Leading up to this activity, students had the opportunity to view 13 videos related to the creation of solid models and drawings. As shown in Table 9, students who watched 12 or 13 of the videos had an average of 14.20 out of 21 concepts present in their files. The average for students who watched 10 or 11 of the videos was 15.00. The average for students who watched between 6 and 9 of the videos was 14.30.

Discussion and Conclusions

Data were collected and analyzed to better understand if viewing the online software demonstrations improved students' performance on modeling activities. The analysis involved assessing student work based upon measureable concepts presented in the video demonstrations. Student work was selected in a manner that assessed near transfer of knowledge and concepts (i.e., simply following the video verbatim) along with farther transfers of concepts where students did similar work without the assistance of step-by-step instruction from the video demonstrations supporting solid modeling.

Similar to previous studies of this course where students' use of video lectures were examined, not all students took advantage of the online materials. For this first look at these few near and far transfer activities, there does not appear to be a big difference in student performance between students who watched the videos and those who did not. This could be explained by several factors. First, the instructor did demonstrate and reinforce concepts in the face-to-face sessions of the class. It is possible that students who did not watch the online videos felt that the explanations given by the course instructor in class were sufficient. Another possible explanation could be that students who did not watch the videos had prior experience in high school with the software. SolidWorks™ is used in about half of the high school drafting programs in North Carolina. A third explanation could be that the explicit objectives introduced in each video were not an exhaustive list of all the concepts present. Pre-instructional objectives consisted of the main ideas that would be presented in the video and were kept to a relatively short list. Students may not have perceived the importance of incorporating previous concepts (far transfer) into their work.

FUTURE WORK

Considering that the researchers only looked at one assignment from the beginning of the semester and one assignment near the end, more research will be conducted analyzing the implementation of these concepts throughout the semester and within more student work. Also in order to further assess the students' ability to transfer the concepts and knowledge gained from the online video tutorials, analyzing concepts present in their final projects will be valuable. This research will provide a stronger basis for understanding what concepts students are able to transfer to a unique environment where no step-by-step videos are provided.

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Mark A. Shreve

Mark Shreve is a master's student in Technology Education within the Department of Mathematics, Science and Technology Education at North Carolina State University. His research interests include multimedia instruction and online learning through all levels of education. Along with completing his degree, Mark is also a graduate teaching assistant for the department's introductory engineering graphics course.

Theodore J. Branoff, Ph.D.

Dr. Branoff is an Associate Professor in the Department of Mathematics, Science and Technology Education at North Carolina State University. A member of ASEE since 1987, he has served as Chair of the Engineering Design Graphics Division of ASEE and as Associate Editor in charge of paper reviews for the *Engineering Design Graphics Journal*. He is currently President of the *International Society for Geometry and Graphics.* Dr. Branoff's research interests include spatial visualization in undergraduate students and the effects of online instruction for preparing technology education teachers and engineers. Along with teaching courses in introductory engineering graphics, computer-aided design, descriptive geometry, and instructional design, he has conducted CAD and geometric dimensioning & tolerancing workshops for both high school teachers and local industry.

Eric N. Wiebe, Ph.D.

Dr. Wiebe is an Associate Professor in the Graphic Communications Program at North Carolina State University. He has authored or co-authored four texts on technical graphics and has been involved in Computer-Aided Design (CAD)/3-D modeling development and use since 1986. He has also worked on the integration of scientific visualization concepts and techniques into both secondary and post-secondary education. Dr. Wiebe is a former editor of the *Engineering Design Graphics Journal* and has been a member of the EDG Division of ASEE since 1989.