AC 2007-1652: ONLINE LEARNING OBJECTS: DO THEY ENHANCE MASTERY OF MECHANICAL ENGINEERING CONCEPTS?

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Online Learning Objects: Do They Enhance Mastery of Mechanical Engineering Concepts?

Abstract

An expanded study is presented to determine whether the use of online learning objects enhances mastery of key concepts in mechanical engineering. Each course in the department has a defined set of required competencies that each student must satisfy in order to receive a passing grade in the course. Multiple opportunities are provided for satisfying each course competency during the semester, including the final examination.

Three introductory mechanical engineering courses, dynamics, fluid mechanics, and thermodynamics were selected for this study. After introducing the concept underlying the given competency in class, students were assigned a homework set that required the use of an online learning object related to the competency. Mastery of the concept was tested using a competency quiz administered during the next class meeting and multiple-choice problems on the final examination.

The performance of students who had used the online learning objects was compared to that of students in previous semesters who had covered the same material and had been assigned similar homework in the traditional manner of chalkboard and written assignments. Differences in the performances of the two groups will be discussed along with a learning styles assessment conducted for the students in both classes. Also, two online learning objects were selected to assist students for two different concepts in two courses to assess whether the instructors choice of the learning objects was an important factor in helping students master course competencies.

Introduction

It has been well established in the literature[1-3] that engineering students are typically visual rather than verbal learners. Nonetheless, engineering instructors still rely heavily on the traditional lectures to teach students. While lectures are often accompanied by sketches on the chalkboard or pictures projected onto a screen, the primary instructional tool is still verbal in nature. All too often the instructional approach is still "instructor-centered" rather than "student-centered."

Accompanying the dramatic rise in the use of the internet in the past ten years has been the development and collection of online learning materials. A learning object is any entity, be it digital or non-digital that may be used for education and/or training[4]. With regard to online learning, these objects can be comprised of Web pages, portable documents, databases, animations, applets, and movies. Online learning objects are increasingly being used to supplement traditional lectures and are becoming an important foundation to the delivery of online courses. Cost-effective and efficient delivery of online learning tools has become a focus in recent years. Several organizations, activities, and consortia, such as Ariadne[5], MERLOT[6], LRX[7], SoURCE[8], and Universitas 21[9], have emerged as leaders of this effort by developing libraries and databases of reusable online learning objects. Activities within these organizations include elements which emphasize design, development, and delivery[10]. MERLOT[11,12], the Multimedia Educational Resource for Learning and Online Teaching, for example is a "referatory" of online materials, meaning that it contains links to the materials and not the materials themselves. It currently contains links to over 12,000 learning objects, including over 400 in engineering alone. In addition, MERLOT provides user comments and peer reviews of many of the learning objects in its collection, with new comments and reviews appearing constantly.

Several years ago the Department of Mechanical Engineering at the University of Memphis established a set of 4-5 "competencies" for each required course in the mechanical engineering curriculum[13-14]. In order to pass a course, each student must successfully demonstrate that he/she has mastered each of the competencies. Various ways are used to test the competency skill, but most often short quizzes are used. Students typically must get the answer to the short-answer quiz problem completely correct in order to satisfy the particular competency. Multiple opportunities are provided for satisfying each course competency during the semester, including the final examination.

A study was undertaken in three undergraduate mechanical engineering courses to determine if the use of online learning objects would help students master the required course competencies. The performance of students who had used the online learning object was compared to that of students in another semester who had covered the same material and had been assigned similar homework in the traditional manner of chalkboard and written assignments. For two classes, learning objects were utilized for two separate competencies to assess whether the learning objects chosen were a significant factor on student performance and student perception.

Methodology

Three introductory undergraduate mechanical engineering courses were selected for this study: dynamics, thermodynamics, and fluid mechanics. The courses were taught by two different instructors, both of whom had taught the courses a number of times in the past. All courses were one hour morning courses offered between the hours of 8:00AM and 10:15 AM Monday, Wednesday, and Friday. In each course, students were made aware during the first class meeting of the course competencies and the fact that all competencies had to be satisfied in order to complete the course successfully.

Early in the semester each student was asked to self-administer the online Index of Learning Styles tool developed by Soloman and Felder[15] and to turn in the results of the assessment. This self-administered online tool poses 40 conjectures to the student. Upon completion of the instrument the student's learning style is characterized and reported to the student in terms of each of the following learning style pairs:

- Active vs Reflective Learning Style
- Sensing vs Intuitive Learning Style
- Visual vs Verbal Learning Style
- Sequential vs Global Learning Style

MECH 3331/CIVL3180: Fluid Mechanics/Hydraulics

Homework Assignment (Fall 2006)

Energy Equation: Online Learning Object

An important special form of the general energy equation is the energy equation along a streamline for incompressible flows which is given as follows:

$$\frac{p_1}{\rho}+\frac{1}{2}v_1^2+gz_1-w_s=\frac{p_2}{\rho}+\frac{1}{2}v_2^2+gz_2+gh_L$$

An online Java applet has been developed to determine the power needed in the pump for the water-jet to pass over the wall. All calculations used in this applet are based on the work-energy equation presented above.

The applet and the instructions for using the applet are available at:

http://www.ce.utexas.edu/prof/kinnas/319LAB/Applets/Energy/Energy.html

Problems:

Use the applet to answer the following questions:

1. For a pump power of 2kW, outlet diameter of 6 cm, and outlet angle of 45°, determine the outlet velocity for a Tank Hight of:
   a. 10m
   b. 8 m
   c. 6 m
   d. 4 m
   e. 2 m
   f. 0 m

   Is the relationship between outlet velocity and tank height linear? Use the energy equation to explain the relationship.

2. For a Tank Height of 10m, outlet diameter of 6 cm, and outlet angle of 45°, determine the outlet velocity for a Pump Power of:
   a. 10 kW
   b. 20 kW
   c. 30 kW
   d. 40 kW

   Is the relationship between outlet velocity and pump power linear? Use the energy equation to explain the relationship.

3. For a Tank Height of 10m, pump power of 20 kW, and outlet angle of 45°, determine the outlet velocity for a outlet diameter of:
   a. 5 cm
   b. 6 cm
   c. 7 cm
   d. 8 cm
   e. 9 cm
   f. 10 cm

   Is the relationship between outlet velocity and outlet diameter linear? Use the energy equation and continuity to explain the relationship.

4. For a Tank Height of 10m, pump power of 20 kW, and outlet diameter of 5cm, determine the outlet velocity for a outlet angle of:
   a. 0°
   b. 20°
   c. 40°
   d. 60°
   e. 80°

   Why does the outlet velocity decrease as the outlet angle decreased? Use the energy equation to explain your answer.

Figure 1. Sample homework assignment using an online learning object.

For this study, the Visual vs Verbal learning style was used to compare the learning styles of the students populating these courses.

Material related to the concept underlying each competency was first presented in class in the traditional manner. This presentation typically included the concept itself (e.g., Newton's Second Law), the pertinent mathematical representation of the concept, and an example problem or two. Students were then assigned a homework set, similar to the assignment shown in Figure 1, which required the use of an online learning object related to the particular competency. Students were surveyed in class immediately afterwards to ascertain their attitude toward the online learning object used. A quiz was given during the next class meeting related to the concept and similar to the way the concept had been used in the online learning object. Finally, understanding of each competency was tested again on the final examination in the course via multiple-choice problems related again to both the concept and the online learning object.

The performance of students who had used the online learning object was compared to that of students in another semester who had covered the same material and had been assigned similar homework in the traditional manner of chalkboard and written assignments.

The learning objects selected for each course were:

- Dynamics:
    - Mass on Incline with Friction (http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html)
- Fluid Mechanics:
    - Energy Equation Along a Streamline (http://www.ce.utexas.edu/prof/kinnas/319LAB/Applets/Energy/Energy.html)
    - Frictional Losses through a Pipe (http://www.freecalc.com/fricfram.htm)
- Thermodynamics:
    - Steam Table Calculator http://www.mathpad.com/

Assessment
Results of the Index of Learning Styles assessment are given in Table 1 for all three courses in the study. A score of -11 indicates a strong dependence on the first of the two learning styles in each pair, while a score of +11 indicates a strong dependence on the second style. Obviously a score of zero would indicate the student is equally dependent on both learning styles in the pair.

Clearly, the students involved in our study are strongly visual learners who remember best what they see rather than what they hear or read. In addition, they are sensing learners who tend to like learning facts rather than intuitive learners who like discovering possibilities and relationships.

While ILS data were not available for the Fluid Mechanics Control Group, the data in Table 1 show little differences in the learning styles of the six groups for which ILS data were collected.

Following the homework assignment that required use of the online learning object, the students were surveyed to ascertain their feelings toward the use of the online material. The survey contained the following conjectures, and students were asked to respond on a 5-point Likert scale that ranged from 1 (Strongly disagree) to 5 (strongly agree). Results of the surveys in the two courses are shown in Figs. 2-6 below. From the surveys it is immediately apparent that the majority (72%) of the students felt online learning objects were beneficial to their understanding of the concept being addressed.

Pop quizzes were given in each of the classes to determine the students' mastery of the competency addressed by the online learning object. The results were compared to the success

Table 1. Results of the Index of Learning Styles Assessment.

Learning Style Pair	Dynamics Study Group 1 (mean ± SD)	Dynamics Control Group 1 (mean ± SD)	Fluid Mechanics Study Group 1 (mean ± SD)	Fluid Mechanics Study Group 2 (mean ± SD)	Thermo-dynamics Study Group 1 (mean ± SD)
ACTIVE/ REFLECTIVE Active = -11 Reflective = +11	**-1.2 ± 5.7**	**-2.0 ± 5.8**	**-1.1 ± 4.8**	**-1.0 ±4.8**	**-0.9 ±4.9**
SENSING/ INTUITIVE Sensing = -11 Intuitive = +11	**-4.5 ± 4.7**	**-3.3 ± 5.3**	**-3.5 ± 5.6**	**-3.3 ± 5.6**	**-3.5 ± 4.7**
VISUAL/ VERBAL Visual = -11 Verbal = +11	**-6.2 ± 4.0**	**-8.5 ± 2.3**	**-6.4 ± 3.3**	**-6.1 ± 3.3**	**-5.6 ± 4.3**
SEQUENTIAL/ GLOBAL Sequential = -11 Global = +11	**-2.7 ± 4.3**	**-2.3 ± 5.3**	**-1.4 ± 4.3**	**-1.3 ± 4.3**	**-1.2 ± 4.7**

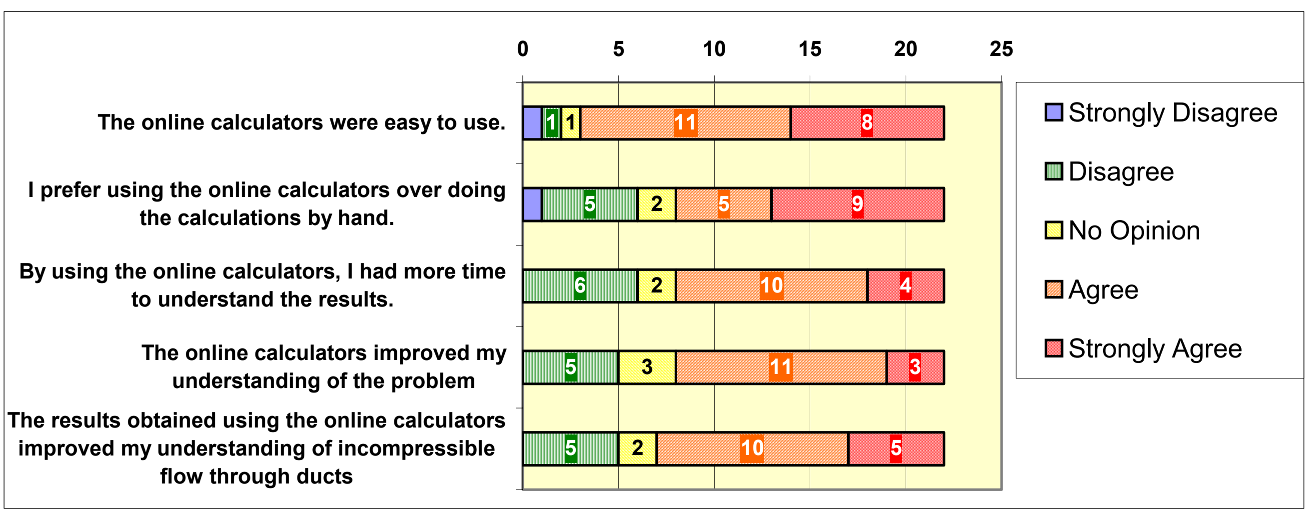

Figure 2. Student survey results for the fluid mechanics study group 1, pipe flow losses

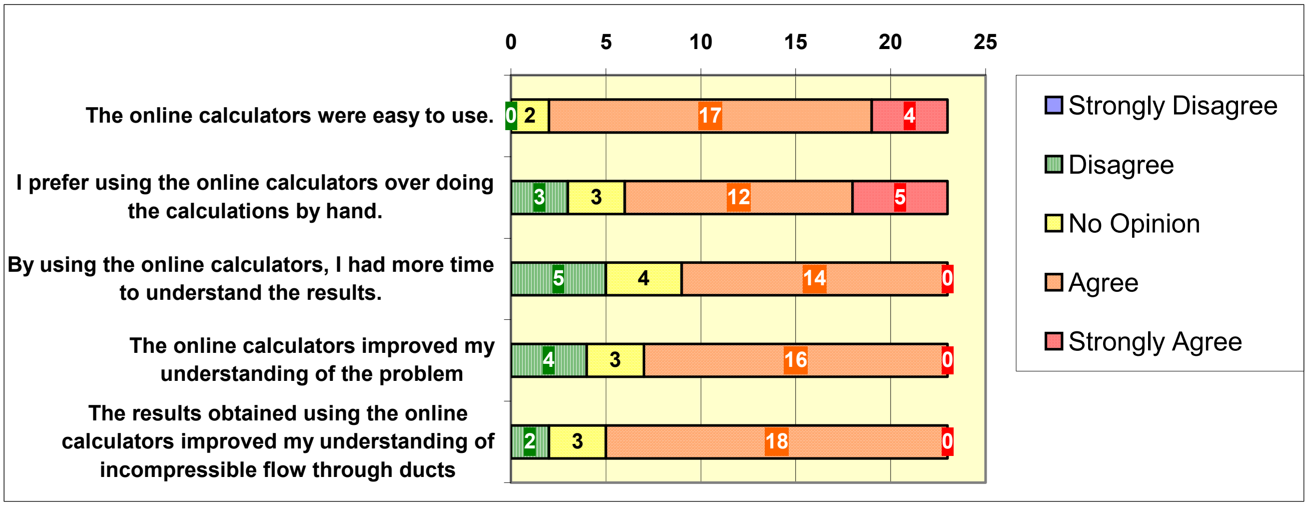

Figure 3. Student survey results for the fluid mechanics study group 2, pipe flow losses

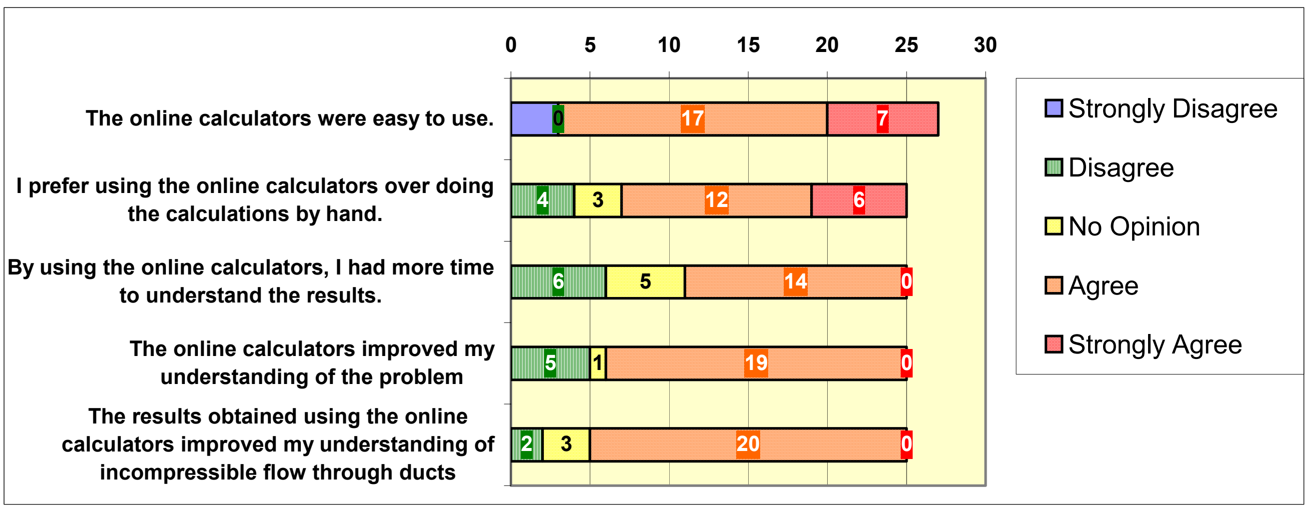

Figure 4. Student survey results for the fluid mechanics study group 2, work and energy

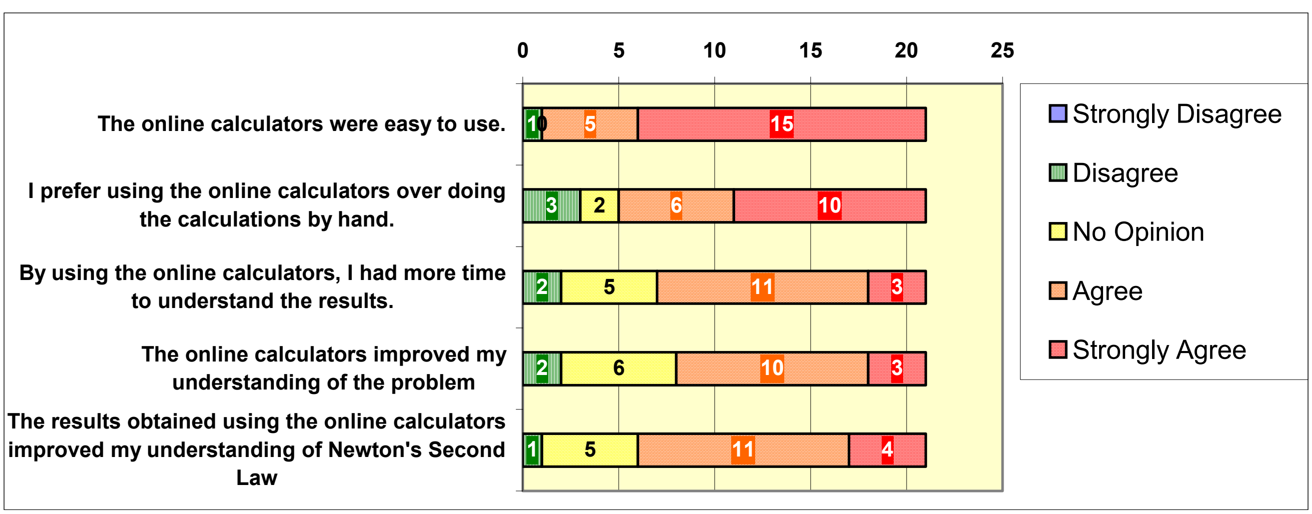

Figure 5. Student survey results for the dynamics study group 1, Newton's 2nd Law

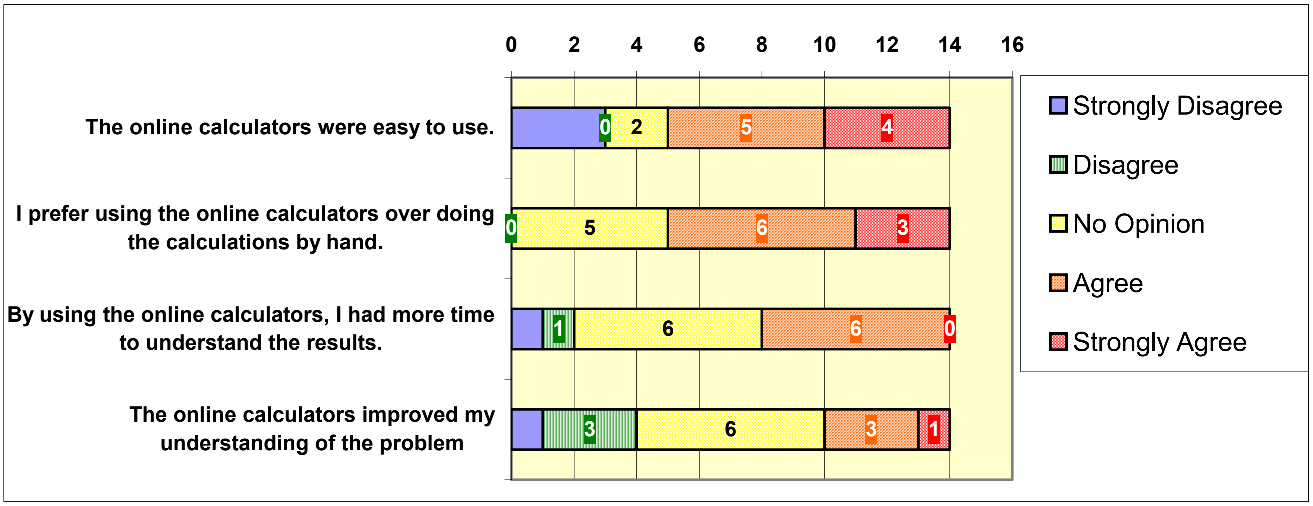

Figure 6. Student survey results for the thermodynamics study group 1, steam tables

rates for the same quiz administered to a class taught earlier (Control Group) using only traditional chalkboard instruction techniques. Results are shown in Table 2. Also shown in the table are the incoming grade-point-averages of the respective classes. Comparing the mean and standard deviation GPA we see that the study groups and the control groups were closely matched insofar as demonstrated ability.

In addition to the short competency quizzes, the final exam in each course also addressed the competencies. The results for the final exams are shown separately in Table 3 below.

Conclusions

It appears that while students perceive that online learning objects improve their understanding of some fundamental concepts in dynamics, fluid mechanics, and thermodynamics, their perceptions were borne out in neither their competency quiz nor their exam performances in this study.

Furthermore, the use of learning objects to supplement two different competency topics within a course did not show a significant difference in the measured performance on either the exam or the competency when compared to the control group.

Additional data must be collected and analyzed in future semesters before a final conclusion can be drawn. The increasing use of visual learning objects justifies the need to continue and expand these studies, perhaps to include engineering programs at other colleges and universities. It can be argued that the student may feel more confident about their understanding of a concept through the use of an online learning object as implied by the survey results. But, is this sufficient justification to continue using learning objects if student performance is not significantly improved? To answer this, one has to resolve whether student performance on quizzes and exams is the only true metric for student success. In either case, an important preliminary conclusion can be made. The use of online learning objects does not appear to diminish student performance and students generally feel that they have increased their understanding of the fundamental engineering concepts evaluated herein.

Table2. Student success rates on competency quizzes

	Dynamics Group 1 (friction)	**Thermo-dynamics Group 1 (Steam table)**	**Fluid Mechanics Group 1 (pipe losses)**	**Fluid Mechanics Group 2 (pipe losses)**	**Fluid Mechanics Group 2 (energy equation)**
Study Group GPA	2.86 ± 0.42	2.97 ± 0.45	2.81± 0.43	3.010± 0.50	3.010± 0.50
Study Group Success Rate	4/20 (20%)	4/16 (25%)	26/29 (90%)	28/34 (82%)	33/34 (97%)
Control Group GPA	2.91 ± 0.65	2.93 ± 0.47	2.86 ± 0.46	2.86 ± 0.46	2.86 ± 0.46
Control Group Success Rate	4/11 (36%)	10/31 (32%)	27/27 (100%)	27/27 (100%)	27/27 (100%)

Table 3. Student success rates on final exam question

	Dynamics Group 1 (friction)	**Thermo-dynamics Group 1 (Steam table)**	**Fluid Mechanics Group 1 (pipe losses)**	**Fluid Mechanics Group 2 (pipe losses)**	**Fluid Mechanics Group 2 (energy equation)**
Study Group Success Rate	11/23 (48%)	100/122 (82%)	14/27 (52%)	14/26 (54%)	6/26 (23%)
Control Group Success Rate	5/10 (50%)	71/90 (79%)	14/20 (70%)	14/20 (70%)	13/20 (65%)

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