

Circuits Learned by Example Online (CLEO): A Video-Based Resource to Support Engineering Circuit Analysis Courses

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Abstract - The “Circuits Learned by Example Online” (CLEO) web-based repository of over 250 worked problems in engineering circuit analysis provides students with a video-based learning tool suitable for self-guided study, homework support, and exam preparation. Each problem offers the complete solution process embodied as a narrated video “screencast” of handwriting and drawings captured from a tablet device; the audio commentary explains each step of the multi-step solution process. The searchable repository matches the organization of leading circuit textbooks, and can also be tailored to a specific course syllabus. Many examples of correct problem-solving strategies are presented, including explanations of why specific strategies are selected among competing approaches. Students report that they consider the CLEO system a useful resource to support their homework activities, as a tutorial to learn more about concepts presented in class, and as preparation materials for exams. Students also reported that the system helped them to better understand course concepts, make efficient use of study time, and improve their problem solving skills.

Index Terms - Circuit analysis, On-line educational resource, Screencast video, Tutorial.

INTRODUCTION

Student retention is a major challenge facing Science, Technology, Engineering, and Mathematics (STEM) education today. As the global marketplace becomes more competitive, engineering educators must ensure that they address the needs of today’s learners. Beginning students often experience difficulty knowing how to conceptualize the big-picture solution process and how to summon relevant facts and strategies at each step of the process. Instructors try to strike a balanced presentation of general theories, facts, problem-solving strategies, and illustrative examples, but it seems that students always want more examples. Students spend most of their out-of-class time preparing solutions to homework sets, so they express a desire for many specific examples. While some students may simply be seeking templates for pattern matching, the fact remains that learning by example is a powerful and effective way for anyone to begin mastery of a new knowledge domain [1].

Observing an expert solve problems in a particular knowledge domain is an early stage in the apprenticeship style of learning [2] in which a learner begins by observing, then tries the activity with frequent feedback from the expert, then with decreasing feedback as the learner becomes more like the expert. Outside of class, students find additional examples in print resources such as textbooks and study guides such as Schaum’s Outline series, online tools such as MIT’s Open-CourseWare [3], and archived online lectures. However, students have limited time to devote to any particular class, and searching through hours of archived lectures for the single needed example relevant to the problem at hand is not feasible. A single “one-stop shopping” web-based repository of worked examples accompanied by expert explanation would be a valuable resource.

The “Circuits Learned by Example Online” (CLEO) project [4] started in 2007 and builds upon a pilot study presented at FIE in 2001 [5]. Students taking engineering circuits courses frequently request many more examples than time permits in class. The CLEO system available at <http://www.rose-hulman.edu/CLEO> offers students narrated videos that explain and illustrate the complete solution process; the video looks similar to an animated white board, and the narrated commentary explains each step. The web-based nature of the system provides world-wide access at any time of the day or night. Many examples of correct problem-solving strategies are presented, including explanations of why specific strategies are selected among competing approaches. The video format allows the rate of instruction to be tailored to the learning needs of the individual student through use of pause, rewind, and fast-forward controls. Video-based tutorials are often more effective than written materials for engineering students who tend to be visual learners [6].

Now in its third year, the CLEO system has been assessed by usage statistics collected by the web server as well as annual student surveys. Students report that they consider the CLEO system a useful resource to support their homework activities, as a tutorial to learn more about concepts presented in class, and as preparation materials for exams (as confirmed by dramatic increases in web server hits days before an exam). Students also reported that the system helped them to better understand course concepts,

make efficient use of study time, and improve their problem solving skills.

This paper reviews the design and implementation of the CLEO system, presents assessment results, and evaluates those results.

APPROACH

Today an enormous body of web-delivered learning materials has been created, much of it freely available to students world-wide. The CLEO system extends this body of work according to the following design criteria:

- Concentrate exclusively on the most critical learning activity in circuit analysis, namely, creating a correct solution to a multi-step problem,
- Make efficient use of the student's limited time and attention span,
- Maximize availability and accessibility,
- Facilitate searchability and navigation of content to find relevant problems,
- Accommodate different styles and rates of learning, and
- Comprehensively cover a standard one- or two-semester circuits sequence taken by nearly all engineering majors.

Each problem in the CLEO database includes a problem statement and circuit diagram similar to established circuits textbooks. An end-point answer is available, and the full solution is presented as a narrated video. The video narration explains each step, and discusses why the problem is solved in a particular way. The videos appear much as the way handwriting and diagrams unfold on the whiteboard in a traditional lecture; however, the pace of the video is accelerated by eliminating time associated with erasures and writing individual letters in text, thereby maintaining student attention. Video solutions are typically 5 to 15 minutes duration. Students can also adjust the pace of the solution to suit their individual needs by using the pause, rewind, and fast-forward controls of the video player.

The problems are delivered by a web server to provide anywhere, anytime access. The problem files are managed by a database backend to permit search and navigation, and to collect usage statistics. Google Analytics [7] has also collected usage statistics for the past two years. The search features include a browse mode in which students narrow down a topic and then see thumbnail images of the circuit diagrams; in this way they can quickly identify those problems that appear similar to their particular problem at the moment. The search features also organize the problems into related areas, and include a keyword search mechanism.

The CLEO system supports multiple languages, and presently offers the video narration in English and in Chinese; Spanish language is a planned future addition. The video narration is also available as text captioning to increase accessibility for hearing-impaired students.

The CLEO database includes over 250 problems, broadly covering the topics of DC circuits, AC circuits,

transient analysis, and Laplace-domain analysis; within each of these topic areas, the coverage includes:

- DC circuits: circuit variables and elements, resistive circuits, nodal and mesh analysis, proportionality, source transformations, Thévenin equivalents, maximum power transfer, superposition, operational amplifiers, and two-port networks;
- AC circuits: circuit elements, sinusoids, phasors, RMS value, mutual inductance, power, frequency response, balanced and unbalanced three-phase circuits, and two-port networks;
- Transient analysis: first- and second-order circuits, initial conditions, natural response, step response, and sequential switching;
- Laplace analysis: circuit analysis methods and two-port networks.

RESULTS

I. First Year

The initial implementation of the CLEO system required students to log in with a unique username to permit individualized statistics to be collected, ultimately with the aim of studying usage behaviors based on GPA, major, gender, and so on. The first-time login procedure included an informed consent statement detailing type of information to be collected and measures taken to ensure privacy of student records. A total of 918 accounts were generated for students at Rose-Hulman as well as three other participating schools.

Website monitoring during the Fall 2006 semester indicated that approximately 30% of the students would complete the registration process required to establish their Project CLEO account. Only 1 to 2 percent of students would come back to visit the site again, and only a small fraction of a percent used the materials enough to be statistically useful in the assessment study. These behaviors were essentially the same for all participating institutions.

A student focus group conducted by Rose-Hulman's Institutional Research and Assessment group indicated that the login process was a major barrier to student interest in the system. In addition, the focus group students indicated that the degree to which professors would encourage their students to use the CLEO materials made a big impact on whether students would consider using the site.

II. Second and Third Years

The login mechanism was disabled the following year, and Google Analytics tracking was added to the site to acquire more detailed usage information. At the beginning of the Fall 2007 semester, the CLEO system was advertised locally on the Rose-Hulman campus to 350 students enrolled in all types circuits courses (for ECE majors and non-majors). In addition, an advertisement was sent to the Electrical and Computer Engineering Department Heads Association

(ECEDHA) mailing list; the system recorded 208 unique visits in less than 24 hours.

During the Fall 2007 timeframe (September 1 through December 31) the CLEO system received 4,164 visits from 2,063 unique visitors who generated 62,045 pageviews (14.9 average pageviews per visit). The average visit time was 11 minutes, and the bounce rate was 23%; a “bounce” signifies a visitor arrived at one page and then left the site again having viewed only a single page). Another 24% of visitors would view 20+ pages per visit.

Figure 1 plots the number of daily visitors and associated page views during the first half of the semester. The first large activity spike of 208 visitors with 3,242 page views on one day coincides with the ECEDHA advertisement and the first round of exams at Rose-Hulman. Subsequent spikes also coincide with exams at Rose-Hulman. In particular, the data point for October 25 shows a modest number of 87 visitors count viewing a proportionally much higher number of pages (3,217), suggesting that these visitors found sufficient value to warrant returning to the CLEO system and spending more time there.

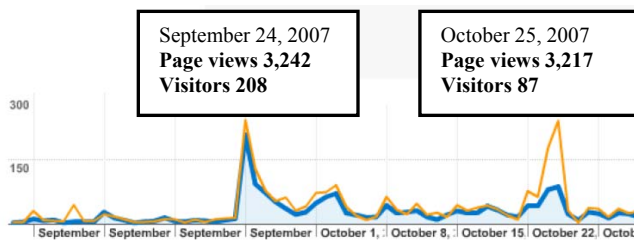


FIGURE 1
VISITORS (THICK LINE) AND PAGEVIEWS (THIN LINE) DURING THE FIRST HALF OF FALL 2007 SEMESTER.

During this same timeframe 26% of visitors persisted for no longer than 10 seconds, a percentage similar to the 23% bounce rate. More than half of the visitors (58%) persisted for at least one minute; 28% remained at the site for at least ten minutes, suggesting that a substantial number of students found CLEO to be a good study tool. “Visitor loyalty” measured according to the number of return visits indicated that about half of all visitors (49%) used the CLEO system only one time, and another 24% of visitors used the system 5 or more times.

From the foregoing data we conclude that a significant number of students found the CLEO system to be a sufficiently useful learning resource to warrant repeated use of the site. Moreover, eliminating the login feature and advertising the system to students and faculty dramatically increased the use of the materials.

At the conclusion of the Fall 2008 semester, a total of 12,687 visits have been recorded from 6,424 unique visitors at an average of 20.8 visits per day since tracking started in the summer of 2007. The visitors viewed a total of 168,976 pages with an average of 13.3 pages per visit. Approximately three quarters of the site traffic originates within the United States, with many of the visitors from

universities, and 15% of the traffic is from referring sites that link directly to the CLEO system. Top universities visiting the system include Rose-Hulman (1,842 visits), the University of Iowa (1,135 visits), and Western Michigan University (670 visits). Note that the latter schools were not contacted directly by us regarding the project, but instead learned of the project either from the ECEDHA mailing list advertisement in Fall 2007 or through an Internet search. The usage patterns over time from these two schools clearly show activity patterns consistent with active use by students enrolled in a course, especially with regular spikes in activity corresponding to exam dates.

Half of the visits were one-time-only visits, 75% of the visits were four or fewer times, while a significant percentage (11%) visited between 9 and 50 times. On average visitors would spend 10.5 minutes accessing the site.

III. Student Surveys

Surveys were administered to Rose-Hulman students at the end of Fall semester in 2007 and 2008. The response rate was 18.8% (66 out of 350 students) in 2007 and 25.4% (89 out of 351 students) in 2008. Most of the survey participants were mechanical engineering sophomores, a consequence of the introductory circuits course serving both majors and non-majors. Half of the survey participants did not try the CLEO system at all, and stated that they did not need the system due to sufficient existing classroom resources; a smaller number stated that they did not know (or forgot) about the system, or that the course instructor did not advocate it. Of those that tried the system at least one time, two-thirds used the system often enough to consider it a useful learning resource, and would use the system once or twice a week. Exam preparation and self-tutoring were cited as the primary reasons to use the system.

Most students who considered themselves regular users of the system reported using the system zero to one time per week, with a few reporting up to 3 or more times per week. Regular users of the system rated the value they received on a 5-point scale by responding to the questions listed in Table 1; the mean and standard deviation is reported for each question. Students gave highest marks regarding the ability of CLEO to help them understand the course and to make efficient use of student time.

Regular users of the system also rated the quality of the CLEO system (Table 2). Students rated the pace of the video solutions and the clarity of explanations the highest, and gave the lowest rating to the search and navigation features.

Regular student users reported the various ways that they used the CLEO system: watch the video as a tutorial without working the problem (24%), prepare for exams (21%), watch video and then work problem (20%), work the problem and then watch the video solution (16%), learn more about concepts presented in class (14%), and work the problem because it was assigned (4%).

TABLE I

STUDENTS' RATING ON THE VALUE THEY RECEIVED FROM CLEO
(5-Strongly Agree, 4-Agree, 3-Neutral, 2- Disagree, 1- Strongly Disagree.)

Value received from CLEO	Mean	Std. Dev.
The CLEO system helped me to better understand the course	3.7	1.2
make efficient use of study time	3.7	1.4
improve my problem solving skills for circuit analysis	3.5	1.3
improve my problem solving skills in general	3.3	1.3
helped me to earn better grades on exams	3.4	1.4

TABLE II

STUDENTS' RATING ON THE QUALITY OF CLEO SYSTEM
(5-Strongly Agree, 4-Agree, 3-Neutral, 2- Disagree, 1- Strongly Disagree.)

Quality of CLEO System	Mean	Std. Dev.
number of problems available	3.6	1.2
pace of the video solutions	4.1	1.1
rationale for particular way problem is solved	3.8	1.0
clarity of explanation	3.9	1.1
effectiveness of search and navigation	3.4	1.1

Students responded to two open-ended questions, "What is the single greatest strength of the CLEO system," and "What is the single greatest need for improvement." To the first question students most often cited seeing the examples worked in real time with the audio explanation synchronized to the writing, as well as the video format itself. They also cited web availability and reinforcement of concepts learned in class as significant strengths. The two greatest needs for improvement included more examples in the database and an improved mechanism for searching and navigating.

CONCLUSIONS

The video-based nature of the CLEO system offers students a valuable resource to supplement their engineering circuit analysis courses. Usage statistics gathered during the past two years show consistent daily use, and activity spikes can be correlated to examination dates. Active use of the system demonstrates that students find value in this resource. Student survey results indicated that students found the most value by using the video solutions for self-tutoring and exam preparation.

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