Using Video Solutions as an Instructional Aid in Teaching Introductory Engineering Circuit Analysis

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Abstract

Regardless of how technology is being used in the classroom as an instructional tool, it is still imperative to the student's learning in all engineering courses to receive numerous examples with step-by-step explanations from the instructor. The question, however, is how can the instructor provide students immediate and step-by-step assistance outside of class while the students are working homework problems or studying the material? Discussed in this paper is the use of video solutions, available via the Internet, as an instructional aid in teaching an introductory engineering circuit analysis course followed by a discussion of preliminary student feedback about the videos of problem solutions. Overall, the students rated their experiences using the videos as very good.

Introduction

During the past decade, research has been conducted in the university classroom in an effort to evaluate and improve different teaching methods in the presence of ever-changing technology [Dick, 3], [Gagne, 5], [National Research Council, 8]. The technology reform movement has led to changes in how instructors of engineering material teach the content and have forced instructors to change their teaching methods [Dufresne, 4], [Jones, 6], [Olsen, 11], [Ruhe, 13]. Educators are now generally agreed that it is possible to improve students' problem solving skills through carefully selected instructional practices. This has led to the emergence of the learning theory known as constructivism that supports many of the changes in the way engineering courses are now taught using technology-based instructional aids. The constructivist reform links directly to the accepted educational philosophies of John Dewey [Dewey, 2] Piaget [Piaget, 12], and Bruner [Bruner, 1], which support students developing new meaning and understanding by integrating new information to their own prior knowledge and experiences. While the constructivist approach to teaching focuses on problem solving, thinking skills, and learning strategies, the focus relevant to the engineering classroom is the emphasis on the students' abilities to solve practical problems rather than on instructional sequences that require students to memorize certain content material. Based on the constructivist theory, the creation of meaningful connections evolves by providing students time to explore relevant problems and to be involved in learning environments that engage the students in developing their own knowledge base. Therefore, when the instructor provides the necessary resources that encourages the students to develop their own problem solving skills, this promotes retention of the material as opposed to the students relying only on the instructor's coverage of the material which promotes rote memorization [Olsen, 11], [Dewey, 2].

Technology is being used in the college classroom in different ways across engineering-related disciplines such as mathematics, physics, and chemistry [Kashy, 7], [Nelson, 9], [Nooriafshar, 10], [Smith, 14], [Wells, 15]. Regardless of how technology is being used in the classroom as an instructional tool, it is still imperative to the student to receive numerous examples with step-by-step explanations from the instructor. The question, however, is how can the instructor provide students immediate and step-by-step assistance outside of class while the students are working homework problems or studying the material? While there are questions from the students in class, it is not until they are outside of class studying the material that they discover they could benefit if they had the verbal

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explanation from the instructor they vaguely recall from class or a verbal explanation of how to work a similar problem for the concepts they are currently studying or trying to apply to their own homework problem. The motivation for the current project was to provide students with instructional aids that would assist them as they studied the material at their own pace and that would facilitate them in developing their own problem solving skills. Discussed in this paper is the use of video solutions, available via the Internet, as an instructional aid in teaching an introductory engineering circuit analysis course. The instructor prepared videos, with audio, of the step-by-step solutions for the following course materials: 1) all examples worked in the classroom, 2) extra examples not worked in the classroom, 3) graded homework assignments, and 4) examinations. In addition, video solutions for homework and examinations from previous semesters were made available to the students as a study tool that they could use at their own pace as they were developing their own understanding of the material. As a result, students were able to repetitively review the solution of classroom examples while reviewing their course notes. Homework and exam solutions were not presented during class time; students were encouraged to examine those solutions at their own convenience, make their own conclusions, and to visit with the instructor to discuss any questions. The time normally devoted to reviewing homework and exam solutions in class was utilized to present additional course materials.

The purposes of this project were to develop the videos of homework and class problems being worked and explained by the instructor and then provide the videos via the Internet to an introductory engineering circuit analysis class to determine if the videos were considered by the students as a beneficial study tool. The research questions guiding this descriptive study were: 1) how do students report using the videos as a study tool?, 2) do the students feel that the use of the videos increases their understanding of the course material?, and 3) what are the pros and cons other instructors should consider when preparing and using videos of worked solutions as instructional aids in their classes? The process for making the video solutions is described below followed by a discussion of preliminary student feedback and lessons learned.

Video Creation

Personal computer technology has advanced rapidly in the past few years. Technologies for video and audio capture have also advanced in this same time period. Several goals were considered before selecting hardware and software for creating the videos. One goal was to have the video solutions be as similar as possible to the instructor working the problems on a whiteboard in the classroom. It was decided that it was not important to have the instructor visible in the videos – only that the student could hear and see the step-by-step solution provided by the instructor. However, files containing captured video can be quite large. Therefore, it was necessary to produce videos that were as small as possible so that a student would not need a high-speed internet connection for viewing the videos. Another goal was to produce videos in a common format that can be played using Microsoft Windows Media Player[®], Apple Quick Time[®], or other video player. Students can download free versions of such software so that they are not required to purchase any specialty software. A final goal was to utilize existing classroom infrastructure to capture "raw" video. This allowed the development of the videos without requiring a large infrastructure investment. The hardware and software selected in an attempt to reach these goals are discussed in the following sections.

Samsung SVP-6000 Video Presenter

The existing classroom infrastructure contained one device which was utilized in video creation. The Samsung SVP-6000 Video Presenter, shown in Figure 1, is an optical device that is capable of projecting transparencies as well as opaque materials and can be used for a variety of applications such as presentations at business meetings, announcements at academic societies, and lecturing at educational institutes. The display functions support the full range of SXGA, XGA, SVGA, and VGA output modes, allowing display on an LCD projector or PC monitor. In addition, the S-video output terminal on the back of the device allows images to be sent directly to a

Figure 1. Samsung SVP-6000

television or VCR. The pick-up device is a 1/2" 1.5 million pixel CCD yielding effective pixels of 1360 (horizontal) x 1024 (vertical) and a frame rate of 7.5 frames per second.

The process for the making the step-by-step solutions began with the Samsung SVP-6000. All circuit diagrams and problem statements were prepared on plain white paper and were generated using a computer or handwritten. Step-by-step solutions for all problems were then worked under the camera on the Samsung SVP-6000. Only the instructor's hand was visible during the step-by-step solution. The Samsung SVP-6000 converted the step-by-step solution into video.

Dazzle Digital Video Creator 150

The next step in the video creation process was to capture the video from the Samsung SVP-6000. The S-video output on the SVP-6000 was connected to the S-video input on a Dazzle Digital Video Creator 150 (DVC 150) (www.dazzle.com), shown in Figure 2. The DVC 150 is an external, USB video capture device. It was connected to a computer via a high-speed USB 2.0 interface, which yielded better video quality than with comparable USB 1.0 products. The DVC 150 has a real-time DVD encoder chip inside that automatically converts video into the MPEG-2 format; this shrinks the video to ¼ its original size, saving hard disk space. The DVC 150 has S-Video and composite video inputs and outputs.

Figure 2. Dazzle DVC 150 Video Capture Device

Even though the DVC 150 has stereo RCA audio inputs and outputs, experience has indicated that it does not capture the audio with the software bundled at the time of purchase in December 2002. This obstacle was overcome by using the sound card in a laptop computer, a headset, and Microsoft Sound Recorder® software. During a step-by-step solution, the DVC 150 captured the video from the SVP-6000 and the audio was captured at the same time using the sound card, headset, and software. The process for combining the video and audio will discussed later in this paper.

At the time of purchase in December 2002, the DVC 150 was bundled with the MovieStar 5 software. Figure 3 shows the MovieStar 5 interface during the video capture process. The window in the upper left containing the circuit diagram was the video captured from the SVP-6000. The video device being utilized for capture, the name of the file into which the captured video was stored, and the resolution of the captured video was also displayed. In addition to capturing video, the MovieStar 5 software also has the capability of editing video and producing the final video.

One of the big advantages of the DVC 150 is its portability. It is a handheld device that can be easily transported and connected to any device that has video outputs. For example, the DVC 150 could be connected to the S-video output on many modern oscilloscopes. Any physical signals measured by the oscilloscope could be captured and stored on a laptop for processing into videos.
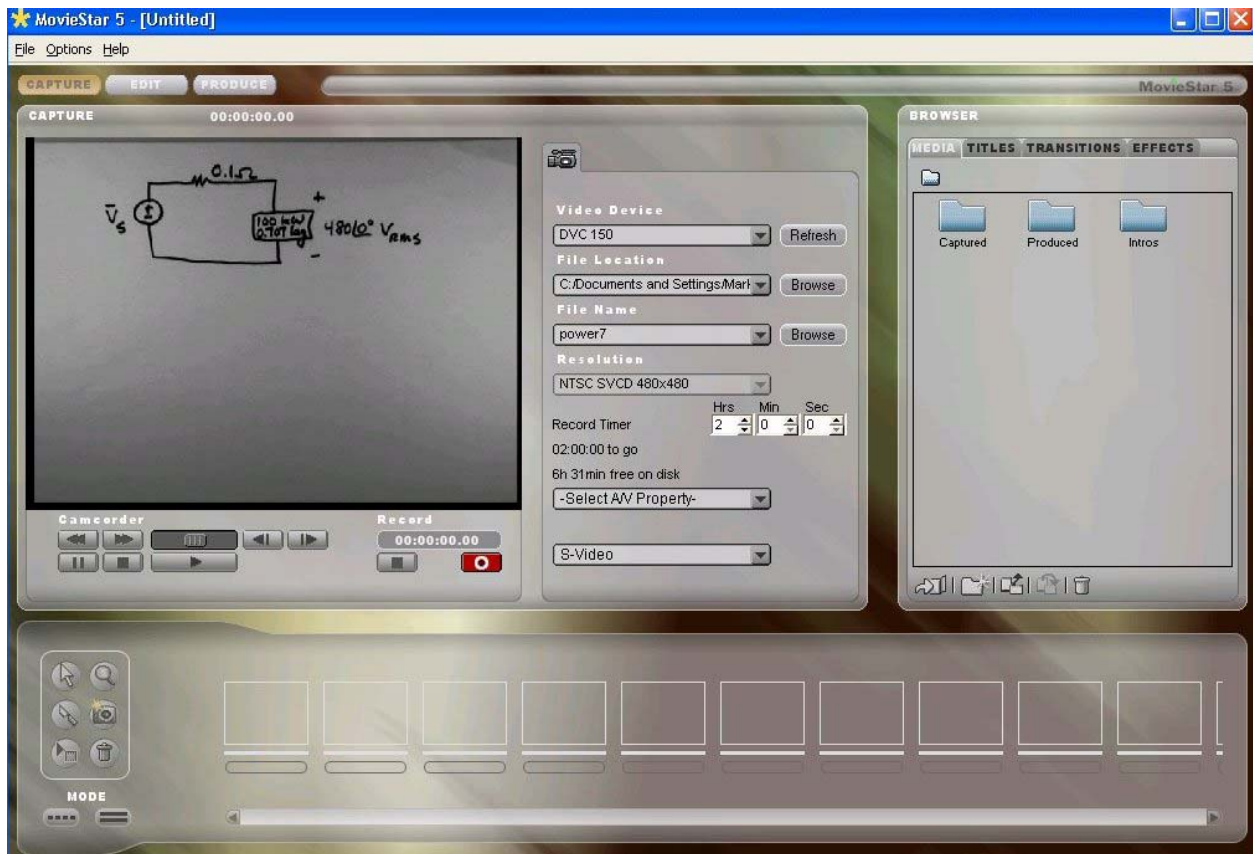
Figure 3. MovieStar 5 Software Capture Interface

The laptop utilized for the video creation was a Toshiba Tecra 9000 with a 1.2 GHz processor, 512 MB of RAM, and 30 GB hard drive. The operating system was Microsoft Windows XP®. A USB 2.0 PCMCIA card was employed with this laptop to interface to the DVC 150.

Roxio Video Wave Creator

The video from the Samsung SVP-6000 was captured using the DVC 150. Because the audio could not be recorded through the DVC 150, it was captured using the sound card on the laptop, a headset, and Microsoft Sound Recorder® software. The procedure for acquiring the video and audio is as follows. The problem to be solved was placed on the SVP-6000. Microsoft Sound Recorder® was started and then the capture function in MovieStar 5 was initiated. At the end of the solution, the video capture was stopped and then the audio was captured. One issue with Microsoft Sound Recorder® is that it has a maximum recording time of 60 seconds. Many of the step-by-step solutions required more than 60 seconds. Microsoft Knowledge Base Article 82215 contains a procedure for increasing the maximum recording time. This procedure was utilized to prepare blank files with durations of six, ten, fifteen, and thirty minutes. An estimate was made of the time required for the step-by-step solution and the blank file of the appropriate length was loaded into Sound Recorder before the solution was started.

Video Wave Creator® by Roxio was utilized to combine the captured video and audio into the final video. Depending on the length of the solution, the MPEG file from MovieStar 5 can be quite large. As an example, a problem utilizing Thevenin's Theorem to calculate a quantity in an AC circuits problem required 7 minutes and 46 seconds of "raw" video; the size of the captured file was 224.3 MB. The audio file for the same problem required 18.9 MB of disk space. The 224.3 MB file was prohibitively large. Video Wave Creator® combined the video and audio files together into a single file with a .wmv extension. This is the default extension for Windows Media Player files. Video Wave Creator® produced a .wmv file with a size of 5.375 MB from these video and audio files.

Descriptive Study Design

Data Collection

This descriptive study consisted of quantitative (measurable) and qualitative (open-ended) data using surveys to collect data at two different times during the semester from the students on the effectiveness of the videos as instructional aids. The quantitative data was summarized and reported using descriptive statistics. The qualitative data was summarized and reported using content analyses. The researcher-developed surveys consisted of five sections. The first section gathered the demographic information and the second section consisted of six statements for the students to rate on a scale of 1 (Poor) to 4 (Excellent) regarding the quality of the videos (e.g. picture quality, sound quality, accessibility). The first two sections of the survey were included only on the first evaluation. The third section was a listing of the five different purposes for which the step-by-step solution videos had been developed by the instructor. The students were asked to check all of the different video options (i.e. previous homeworks, class examples, previous tests, examples not covered in class, and homework solutions from the current semester) they had used as part of their studying of the course material. The fourth section was questions and statements the students rated on a scale of 1 (Never or Disagree) to 4 (Always or Agree) to determine the students' perceptions of the effectiveness of the videos as a study tool. The last section provided the students the opportunity to give more details to support the previous quantitative results by answering open-ended questions relating to technical (or other) problems they had encountered, when they used the videos during their study, and their suggestions for improving the videos of problem solutions.

Results and Discussion

The surveys were administered twice during the semester to 44 students in an introductory engineering circuit analysis course but each time one student chose to not participate resulting in a total of 43 students participating in the evaluation. Of the 43 students participating in the study, there were 25 sophomores, 17 juniors, and 1 senior with 11 of those being transfer students. All but 12 of the students had taken an engineering course prior to this study. The majority of the students reported they used the computer regularly in their courses with 35 using the computer daily in their courses while 6 used the computer weekly. One of the remaining two students reported they used the computer monthly while the other student reported they never used the computer in their courses. Likewise, there were several students who chose not to use the videos. The number of times the students reported using the videos at the first and second evaluation points of the semester are given in Table 1 and Table 2, respectively.

Table 1. Students' Initial Frequency Using Videos

Number of times	Frequency
0	4
1 – 3	7
4 – 6	9
7 – 9	7
+10	16

Table 2. Second Frequency Check Using Videos

Number of times	Frequency
0	2
1 – 3	7
4 – 6	10
7 – 9	8
+10	16

These results indicated the students' frequency of using the videos did not change. Basically, the students were consistently using the videos for their own studying purposes throughout the semester. To determine how the

students were using the videos as a study tool, the five ways for which the videos had been developed were listed. The students were asked to check all of the different video options they had used to study the course material. A summary of their responses is given in Table 3.

Table 3. Use of Videos as a Study Tool

Options to use videos as a study tool	Frequency*
Homework from previous semester	35
Homework from current semester	34
Class examples from current semester	30
Other examples not covered in class	11
Previous test solutions	24

*Students could choose more than one response

With the exception of the "other examples not covered in class," the students were using all of the videos. The students were asked as part of the second evaluation how they had used the videos of problem solutions as a study tool since the first evaluation and the results were almost identical with the exception of two areas. The students reported an increase of use of the videos to study the other examples not covered in class (an increase of 7) and the previous test solutions (an increase of 9). In an effort to further explain the quantitative data summarized in Table 3, one of the open-ended questions in Section V of the survey was asked to determine at what point in their studying did the students report they used the different videos. The results are provided in Table 4.

Table 4. When Students Used Videos as Study Tool

Task	Frequency*
Work homework problems	30
Clarify notes from class	14
Study for tests	8
Compare approach used to work problem to method taught in class	6
Better understand examples in textbook	2
Study topics of power, super nodes, and KCL/KVL Laws	2

*Students could provide more than one response

Approximately one-third of the students (14 of the 43 students) were reviewing the class examples as they studied the material. This was providing the students assistance outside of class as they were studying the material at their own pace. The majority of the students reported using the videos mainly for figuring out how to solve their homework problems. The instructor's procedure for assigning homework was to give the final answer but the homework solutions were not posted online until after the students turned in their worked homework problems. However, the homework solutions from the previous semester which required similar procedures to solve were posted for the students to use while working their homework problems. Therefore, the students were able to use the step-by-step solutions from similar problem to assist them in developing their own problem-solving strategies. To further investigate at what point the students were using the videos to help them work the homework problems, each of the 30 responses was categorized as either before, during, or after working the homework problems and the results are given in Table 5.

Table 5. When Students Used Videos for Homework

Task	Frequency
Before working homework problems	5
While working homework problems	18
After working homework to figure out what was wrong or to compare procedures	7

Those students who reported using the videos prior to working the homework problems indicated they did so because they needed help getting started or did not understand the problem and were seeking more information so they could work the problem. The majority of the students used the videos while they were working the homework problems because they were either stuck or were seeking reassurance that their procedure for the working the

problem was on the right track. Once again the students were exploring for themselves the resources needed to solve the problems as opposed to memorizing a problem as a means of trying to understand the concepts. Finally, there were students who reported they worked the homework problems and then downloaded the previous semester's homework solution file to compare the procedures for working the problems or to figure out what was wrong if their answer was incorrect.

As with any new instructional approach, there are always advantages and disadvantages each instructor must consider. As shown in Table 5, the students used the previous homework solutions to assist them throughout the process of working their own homework problems or to check their procedures. Whether the student used the videos before, during, or after working the homework solutions, the instructional aids encouraged the student to apply their problem solving skills by learning how to apply the concepts to different problems. Therefore, because the students were using the videos, what were their suggestions for improvement? The video quality and accessibility results are given in Table 6.

Table 6. Students' Ratings of Class Video Quality

Quality Item	Average
Picture quality	3.0
Sound quality	3.1
Accessibility via the Internet	3.2
Suitability of content via videos of problem solutions	3.2

With an average of approximately 3 (Very Good) out of 4 (Excellent) for each of the quality factors, the students seemed satisfied with the quality of the instructional aids. However, there were some technical and user-friendly issues that the students encountered and, if corrected, could improve the videos. The students' responses when asked to list all of the technical (or other) problems they had experienced are categorized in Table 7.

Table 7. Problems Students Experienced When Using Videos

Problem	Frequency*
None	23
Slow connection	5
Large files and long downloads	4
Files not compatible with Macintosh computer	2
Must choose Windows media player each time	2
Explanations too fast and controls don't always work to go back	2
Files must be downloaded and then viewed	1

*Students could provide more than one response

Basically, the majority of the students had not experienced any technical (or other) problems. Even though the frequency of the remaining items listed was low, each one provided a valuable suggestion for instructors to consider during the development stages of instructional videos of step-by-step solutions that will be used by students. The problems associated with the slow connections, large files, and compatibility issues should be investigated by the instructor as the software and equipment is being selected to create the videos. The last open-ended question asked the students to list their suggestions for improving the videos. A categorized summary of their responses is given in Table 8.

Table 8. Students' Suggestions for Improving Teaching Method

Suggestion	Frequency*
None	16
Higher quality videos (e.g. sound, picture)	4
More examples as difficult as the homework	3
Improve how videos are viewed and controlled by user	3
Decrease file size	3
Slower and more in-depth answers with reasoning behind each step	3
Label video files more descriptively	2
Make compatible for PC and Macintosh	1
Include section of video answering frequently asked questions	1

*Students could provide more than one response

The majority of those students offering suggestions for improvement liked the videos of problem solutions as a study tool. Of the 16 who reported no suggestions, 7 of those added an additional comment indicating they felt the videos were already very good as they were. This indicated that even though there were some technical and user-friendly issues that can be corrected, the students liked the novel idea of using videos of step-by-step solutions as an instructional tool. The two categories of suggestions relating to slower and more in-depth answers and a section of frequently asked questions suggest that those four students feel those are factors that would enhance their ability to better utilize the videos. But most importantly, did the students feel the use of the videos of problem solutions increased their understanding of the material? On a scale of 1 (Disagree) to 4 (Agree), the students responded with an average rating of 3.2 out of 4.0. Therefore, their overall experience using the videos was "very good". However, further investigations are needed after improvements are made and more data is collected on the students' learning styles and studying procedures.

Instructor's Lessons Learned So Far

1. By providing the problem solutions to homeworks and tests using the videos, the amount of time available to spend on the more difficult concepts has increased and additional material can now be taught. This results in a more comprehensive introductory course that provides the students the foundation they need.

2. Based on the students' emails and questions asked, the students experienced very little difficulty understanding the verbal explanations provided on the videos of worked solutions. They used the videos to answer their own questions because many of the questions previously asked were no longer necessary or were more focused and dealt with the content issues after they had completed or almost completed their own approach to solving the problem. The students no longer came to the instructor asking how to simply work a problem. Instead, they asked more "why" and "how" questions which demonstrated that the students were developing their own problem solving skills and relying more on the instructor as a facilitator. As a result, the students were no longer passive learners and hopefully retention was increased. Further data collection is needed to evaluate the students' retention rates.

3. After having created many of the videos of worked solutions, there are several things that instructors should be aware of to save time and effort in their own development efforts. First, all solutions should be prepared in advance prior to capturing the video. This streamlines the process of capturing the audio and video when the material is organized ahead of time. Secondly, attention should be given to whether the equipment to capture the audio and video is readily available for the instructor to use or is scheduling necessary. Finally, instructors should be aware that this is a two-stage process that does require a significant amount of time to complete. However, with experience, the video preparation time required for those videos prepared for this study was decreased by a factor of approximately one-third.

Future Investigations

The preliminary results reported in this study indicated that the students used the videos as they applied their own strategies to work the homework assignments and based on the students' input, there is potential for expanding the project in an effort to further address the students' learning and studying processes. Therefore, the following avenues for further investigation are in progress:

1. As shown in Table 4, some of the students specified the topics they were studying when they accessed the videos for assistance. Therefore, there is the possibility that there are certain content areas that students need the videos as study tools and there are content areas where the students feel they do not need the additional instructional aids. Therefore, it may be determined that there is not a need to do weekly videos but only those needed for specific topics based on the tracking results of which topics students choose and report are more difficulty to understand.

2. Because this study was based on developing an instructional aid that allows students the time to study the material at their own pace and convenience, it is essential to identify those factors that will improve the instructional tool so it is conducive to the students' learning styles and the processes they use to study the specific content. The results in Tables 4 and 5 indicated that there is potential in developing these videos such that they complement the way students use the videos and as a result, develop their own problem solving skills. The focus is on developing the videos such that the students' learning and studying procedures are enhanced and provide the students with a more concrete understanding of the material.

3. In order to make the videos more user friendly, all options for the type of software and equipment that can be used to create the videos is being investigated. One option for creating the step-by-step video solutions is to use a Smart Board from Smart Technologies, Inc. (www.smarttech.com). This is an interactive whiteboard that can be utilized to record mouse clicks or electronic ink. The instructor can use their finger as a mouse or write notes on the durable, low-reflective surface or write over the top of any computer application, write and edit notes, and save everything in a single file. The Smart Board features include Notebook software, which captures annotations and saves your notes, SMART Recorder (Microsoft Windows systems only), which saves audio and data for playback as a synchronized file, and SMART Video Player, which enables the instructor to write over the top of moving or still video.

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