AC 2011-1618: AUDIO-VISUAL LAB TUTORIALS TO DEVELOP INDEPENDENT LEARNERS

Deborah Walter, Rose-Hulman Institute of Technology

Dr. Deborah Walter is an Assistant Professor of Electrical and Computer Engineering at Rose-Hulman Institute of Technology. She teaches courses in circuits, electromagnetics, and medical imaging. Before joining academia in 2006, she was at the Computed Tomography Laboratory at GE's Global Research Center for 8 years. She worked on several technology development projects in the area of X-ray CT for medical and industrial imaging. She is a named inventor on 9 patents. She has been active in the recruitment and retention of women and minorities in engineering and currently PI for an NSF-STEM grant to improve diversity at Rose-Hulman.

Audio-Visual Lab Tutorials to Develop Independent Learners

Abstract

This paper describes the development and use of audio-visual lab tutorials in undergraduate level circuits courses. The tutorials supplement the lab experience by providing 1) basic information on how to set-up the equipment used in the lab and 2) demonstrations of best practices by an expert user. The tutorials demonstrate specific tasks germane to the less experienced student. Students are asked to review certain videos before attending the lab class. Tutorials are also on-line and available for review while students are in the lab. Students' use of the on-line tutorials encourage independent learning and allow the instructor to spend more time relating the measurement exercises to the concepts taught in the lecture. This paper reports on the novel approach of using audio-visual tutorials to supplement the laboratory instruction with the goal of developing independent learners. Assessment data was collected to determine the students' use of the videos tutorials and their perceptions of the value of the resource. Based on our experience, the use of lab tutorials reduce the time students are in the lab, accommodate varied levels of experience and learning styles, develop students' capacity for independent learning, and are preferred by most students over text-based resources.

The rational and need for video-based lab tutorials

Increases in system complexity, the pace of innovation, and the changing job market have combined to require that graduates have a solid foundation in engineering, measurement and testing skills, regardless of their engineering discipline[1]. In order to become life-long learners, students must develop a capacity for independent learning[2]. Thus, creating opportunities for independent learning is arguably the most important part in engineering education. Laboratory exercises are a fundamental part of the education process, helping to create experiential learning environments and to build students' intuition based on the inter-relationship between theory and practical experimentation.

It's commonly accepted that laboratory exercises are a critical component to developing engineering skills. Lab classes represent a significant portion of curricula of all engineering disciplines. Lab exercises in introductory courses are commonly designed to illustrate and demonstrate known concepts or scientific laws. Students also learn practical skills associated with the measurements techniques and experience in the use of modern instrumentation. Other goals of the lab experience are to sharpen observational skills, work in teams, and develop a capacity for independent learning by encouraging students to make self-directed inquires and explorations. Research in how students learn suggests that when students are actively engaged in the course material they maximize their understanding[3]. Therefore, the laboratory experience is both a critical and a potentially rich learning environment for the development of engineering knowledge and skill. However, several recent trends present challenges for engineering educators to overcome in order to create the optimal lab experience.

Challenge 1. Resource limitations and restricted time and space

Due to limited funds, a lack of existing equipment, limited resources for maintaining such equipment, and a lack of available laboratory space, the time and space available for lab courses is limited. The recent availability of inexpensive, mobile lab devices, or computer-based virtual instruments could mitigate the limitations on space and resources by providing an inexpensive measurement set-up (see Ma and Nickerson[4] and references therein). However, even if equipment and space are available, the instructor's time is also a limited resource. Lab tutorials can maximize the instructor's time in the lab by providing basic instruction outside of lab-time.

Challenge 2. The rapid changing pace of technology.

It's important to train students in the use of modern measurement equipment (ABET criteria – outcome k[5]). Engineering departments are therefore constantly striving to upgrade their laboratories and outfit them with the latest technology. Recently technology is changing so fast that it means that students may be exposed to many different measurement platforms over their schooling career. In one sense this experience is valuable because it prepares students become adept at using new equipment. However, it also means significant amount of lab-time is spent to become familiar with the set-up and mechanical manipulation of the new platform. Lab tutorials can be used to instruct students on the new platform without using valuable lab-time.

Challenge 3 Diverse student backgrounds and lack of 'tinkering' experience.

In years past, most engineering students developed a capacity for measurement or hands-on skills before entering college. These days, it is less likely that a majority of incoming engineering students have been 'tinkering' in their garage. In fact it's more likely that students have computer skills or programing experience but have never used a measurement device. A lack of hands-on experience is often suggested as a reason for the gender gap in certain engineering disciplines[6]. Even if this lack of experience is a factor for female engineering students, it is also true that many young men are entering the engineering disciplines with little or no tinkering experience.

Students with limited hands-on experience are often intimidated by the equipment and less willing to experiment on their own especially when matched with a more experienced or confident partner. The use of lab-tutorials which can be watched before lab can help reduce the 'hands-on' gap and increase the confidence of students who have little previous experience in measurement exercises. The increasing diversity of the students entering engineering has resulted in a widening of the backgrounds and experience level of the students in the lab class. It is a challenge to meet these diverse needs in a group setting. The lab tutorials then become a valuable tool to assist students in self-paced learning.

Challenge 4. Multiple languages and diverse learning style

Traditionally, laboratory exercises that instruct students on the operation of instruments and basic measurement techniques are presented in a written lab manual. For a novice student unfamiliar with the equipment, or for who English is a second language, these written instructions can be confusing and frustrating. Text based instruction is not optimally geared for the active and visual learning styles of most engineering students. For example, global learners get frustrated with the tediousness of step-by-step detailed instructions[7]. The incorporation of the lab tutorials in addition to the text-based resources help instructors to provide additional resources that match their learning style more optimally.

Description of the course and laboratory activities

This paper describes the development and use of audio-visual lab tutorials used in three different undergraduate level circuits course: 1) DC circuits, 2) AC circuits, and 3) Circuits and Systems covering both AC and DC for non-electrical engineering majors. The three courses are taught at a small, private engineering institution in the Midwest and the overwhelming demographic of the student population is white male. Student majors include: electrical, computer, mechanical, biomedical, optical engineering, math, and physics. The courses cover basic circuits concepts taught in the sophomore year. Topics taught include Kirchhoff's Laws, nodal and mesh analysis, Thevenin's theorem, superposition, source transformations, AC power, maximum power transfer and operational amplifiers. These courses include 3 hours of lecture and 3 hours of lab per week. Students work in self-selected teams of two and are monitored by an instructor. Each week, the teams of two are required to document their work by keeping a lab journal. The lab journal is turned in at the end of the lab period. Team members trade-off the set-up and write-up roles every other week. A total of 9 labs are required for each class in each course students, students demonstrate their lab skills independently by completing a lab-practical test, usually in the 10th week. While lab exercises are moderated by an instructor, the lab practical test is an individual evaluation of a subset of the skills required in the lab exercises.

Lab Tutorial Description

The tutorials supplement the lab experience by providing basic information on how to operate the equipment used in the lab. A total of 14 "How-To" tutorials have been created that are specific tasks germane to the first-time or non-experience student. A list of the most used "How-To" videos, their length, and a description of the information conveyed is described in Table 1. The number of hits is the number of times (since fall 2010) that the videos have been accessed; this reflects the relative popularity of the topic.

Basic "How-To"Tutorials	**Video Length (m:ss)**	**Description**	**Number of hits**
How_to_Breadboard	1:45	Explains the connections in a standard breadboad	65
How_to_measure_R_with_DMM	1:00	A digital multimeter is used to measure resistance of a standard resistor.	53
How_to_measure_V_with_DMM	1:38	Uses the multimeter to measure voltage across a resistor in a simple series circuit.	41
How_to_measure_I_with_DMM	2:31	Uses the multimeter to measure current through a resistor in a simple series circuit.	56
How_to_setup_DMM	2:19	Combination of the previous three. Useful as an overview of how to use the DMM.	50
How_to_use_DCPowerSupply	2:00	Demonstrated the connections and how to set the voltage and current limit of a DC power supply.	160
How_to_read_ResistorCode	1:51	Describes the standard resistor color code and demonstrates how to read a 2.4kΩ resistor.	85

How_to_use_function_generator	4:44	Demonstrates how to make connects and set the parameters in a function generator to generate a 5Volt signal at 2 kHz. Verifies the signal by measuring with an oscilloscope	37
How_to_FG_HighZmode	0:32	Demonstrates how to change the input impedance of the function generator.	32
How_to_adjust_scope_display	1:41	Demonstrated how to adjust the time and voltage scaling for optimal viewing. Shows how to read interpret the scale.	31
How_to_power_op_amp	10:00	Explains and demonstrates how make pin connections to a standard op amp chip. Shows the set-up and measurement of a simple inverting op amp circuit.	46

Table 1. "How-To" lab tutorials created to instruct students in the basic measurement skills in undergraduate electrical circuits courses.

Example of a lab tutorial

The functionality of the tablet PC was extended by connecting it to a video camera. The settings and outputs of the lab equipment are displayed on the camera window of a computer screen and the schematic of the circuit is shown on another window simultaneously. To explain the measurement system, the instructors explain the test circuit by drawing and writing on a computer-hosted digitizing tablet while the results of the measurements are displayed on the camera window. A screen capture program captures video frames and audio of the instructor's commentary.

The digital multi-meter (DMM) is a ubiquitous instrument used to measure resistance, voltage, and current. It is important for the students to know how to configure the instrument to work in each of the three modes. Typically the instructor will spend 10-15 minutes explaining and demonstrating the correct use of this instrument. In the video *How to use the DMM*, the instructor describes how to set-up the instrument to make measurements in three different modes. The student is shown a schematic of the front panel of the instrument. The operation of the buttons is described using Camtasia[8] to capture the instructor's audio and pen-based notations. Next, the video tutorial captures the instructor demonstrating how measure the resistance of a resistor using the instrumentation that the students will use in their lab in the video titled, *How to measure Resistance with DMM*. Two other tutorials, *How to measure Voltage with DMM* and *How to measure Current with DMM*, are demonstrations of using the actual instruments to make these measurements. The video-based demonstrations are augmented with pen-based explanations of how the measurements they make related to the circuit analysis that they learned in lecture, similar to an explanation that an instructor would make on a white board. Figure 1 (left) captures the pen strokes as the instructor explains how to set up a simple circuit to measure the current by drawing on a circuit schematic. Figure 1 (right) shows the instructor demonstrating how to make the current measurement.

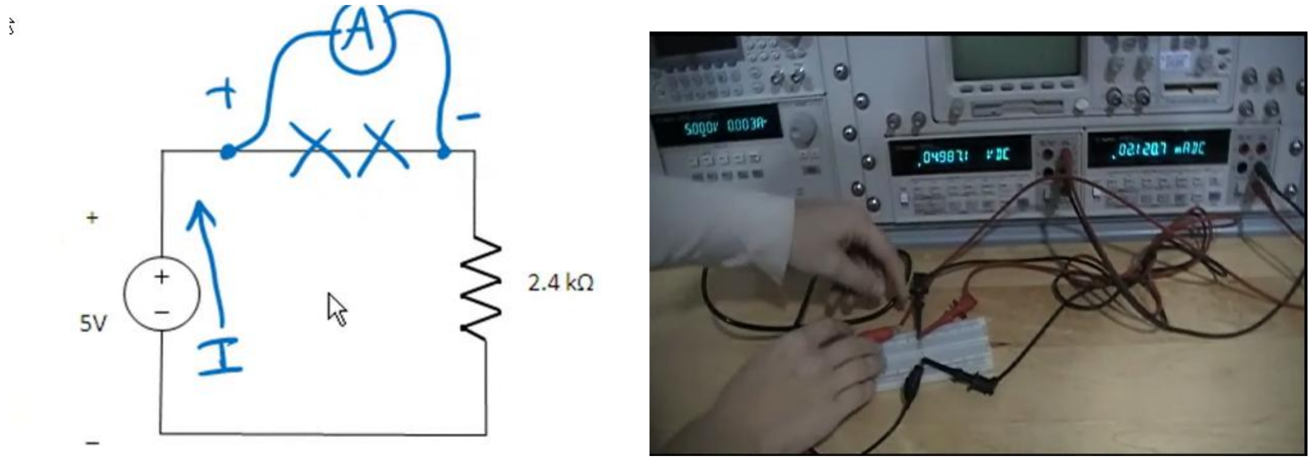


Figure 1 Example of a lab tutorial. (left) The instructor is explaining how to measure current on a circuit schematic. (right) The instructor is demonstrating how to measure the current.

Use of lab tutorial in conjunction with the lab

Students are asked to review certain videos before the lab class. Also tutorials are on-line and available for review while students are in the lab. The pedagogical approach is to use video-based lab tutorials to develop independent learning skills, by accommodating variable levels of experience and learning styles.

The lab tutorials are not meant to be used in a distance learning course, but it's possible they could function in that role. The function of the lab tutorials in conjunction with the lab class is more akin to the 'inverted classroom' approach because they are meant to utilize instructor-guided time more optimally, by using out-of-class time to instruct students on the mechanical or instrumental set-up. However, the lab tutorials have a unique role to play, because in addition to using in-class/lab time more optimally, the availability of the tutorials during lab and in subsequent labs encourages students to act independently to solve their own problems. For example if a student is not measuring the current value that they expect, or they are not sure that they have set-up the current meter in series (a critical and often difficulty skill to learn) they can review the "How-To" video on measuring current and very often correct their set-up to measure the correct value.

Research questions to answer and data collection plan

Several assessments were made to investigate the answers to two broad research questions, which are described below.

1. Do students prefer video lab tutorials over text-based resources?

Based on past experience students preferred viewing narrated videos of solved example circuit problems over reading similar examples in the text. It is reasonable to think that students would also prefer to watch an expert set-up and make measurements, rather than read about the procedure. A post-class survey was used to rate students preference for the video tutorials, compared to text-based resources. In another course, students were asked to self-report their use of the video tutorials each week. Some statistics can be gathered to determine the number of times each video has been accessed, however it is not possible to track which student is watching each video, or how many times the same student is watching the same video.

2. Do video lab tutorials accommodate a diversity of learning paces, and previous experience?

Another area of study was focused on what potential benefits are gained by using the lab tutorials in the course. No matter how precise and detailed the written lab procedure, some students can completely misinterpret the basic instructions. Most often students who have very little past experience with instrumentation have difficulty following the basic instruction. This leads to frustration and sometimes long waits to get the instructor's attention to correct the problem. Some instructors have addressed this concern by demonstrating the basic set-up of instrumentation in a group format, but the group instruction does not accommodate various learning paces. In one course with 4 sections, we compared the use of the video tutorials with the group instruction approach and measured the total time it took to complete each lab. Another survey was used to assess the level of the students past experience, their learning pace, and how well they felt their pace was matched to their partner. We also asked students to rate how strongly they agreed or disagreed with potential benefits of the tutorials.

Results

The audio-visual lab tutorials have been used in three different undergraduate level circuits course: 1) DC circuits, 2) AC circuits, and 3) Circuits and Systems covering both AC and DC for non-electrical engineering majors. Three studies associated with the lab component of these courses are discussed below.

A study of students' preparation and performance in lab

It has been observed that some students seem to perform adequately during the lab but cannot demonstrate these skills when they are tested individually Anecdotally, the authors observed several behaviors that could attribute to this phenomenon. It has been observed that sometimes one partner, with more hands-on experience, takes control of the experimental side and the other team member does not get enough practice. Some students work exceptionally well in the team-based activities of the lab, and may as a consequence not develop individual skills that help them to excel in the autonomous lab practical skills test. It could also be that the lagging student feels less confident when working on their own, which could lead to mistakes and lower their score on the individual practical skills test. A survey was conducted and administered at the end of the Circuits and Systems course to gauge students' preparation for lab. Three factors were studied to determine if they predict student lab performance as measured by the grade earned in the individual lab practical test:

1) students' previous level of 'hands-on' experience,
2) students' self assessment of lab skills and teamwork
3) students' self assessment of test anxiety

Of the 210 students enrolled in the Circuit and Systems course during the fall quarter in 2007-2008, 64% of the students responded to the survey. The course was taught in 9 sections, with a total of 6 different instructors. Among the 135 students who responded to the survey, 28 (21%) were female and 107 (79%) were male.

Students rated how much hands-on experience they had prior to the start of the course by responding to a number of prompts. For example, experience with household wiring, experience with computer hardware, experience with auto-mechanics, etc. The correlation of previous experience with performance was only slight. Considerable range of experience levels were reported among both male and female students.

Students were asked how well they worked with their partner and how they ranked their lab skills compared to their partner's (See text box in figure 2)

There were very few issues due to poor teamwork that were reported and those that reported poor teamwork performed on average the same as those who had good teaming experiences. Good working teams got good lab report grades, but good teamwork did not necessarily translate to better performance on the lab practical exam. Students that scored high on the lab practical reported more often that they are 'more skilled than my partner'. Students who reported that their 'partner understands more than me or gets it faster, but I do my share of work' performed on average 10 points lower than those who reported that they are 'about the same level'.

How well do you think you and your partner worked as a team this term?

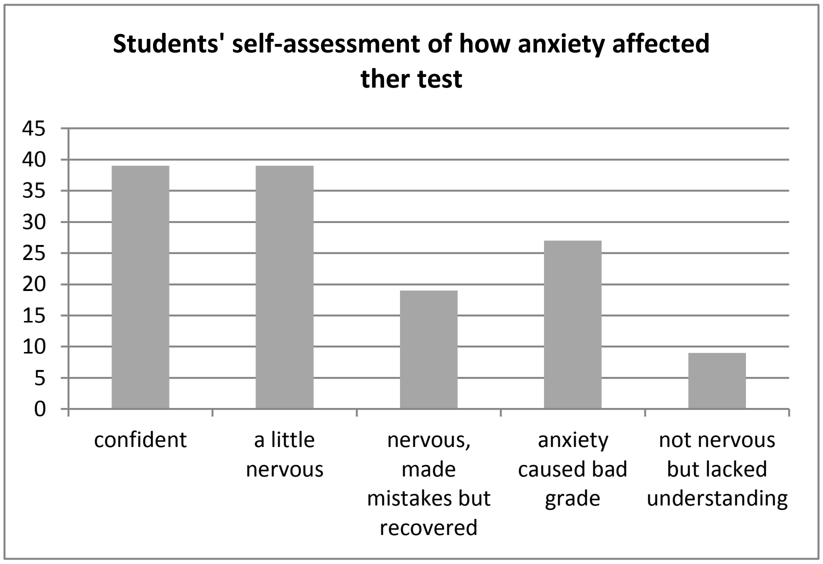
- ☐ Very well
- ☐ About average
- ☐ Not very well

How do you compare your skill level with your lab partner's skill level in the lab activities?

- ☐ I understand a lot more or a lot faster than my lab partner and I usually do most of the work
- ☐ I understand more faster but we do about the same amount of work
- ☐ We are at about the same level
- ☐ My lab partner understands more than me or gets it faster, but I do my share of the work
- ☐ My lab partners understands a lot more and gets it faster, so to save time my partner does more of the work

Figure 2 Questions to assess teamwork issues

Students were asked to assess their anxiety during the lab practical test and how that might have affected their performance (see figure 3). Student anxiety was slightly anti-correlated to their test performance; meaning student performed worse on the test if they reported that they were nervous. However, only 20% of the students reported that anxiety caused them to perform poorly.



During the lab practical test do you think the pressure of the test affected your performance?

- ☐ I was confident and I didn't make any major errors
- ☐ I was a little nervous, but it didn't affect my performance
- ☐ I was nervous, which caused me to make mistakes, but I was able to fix my mistakes within the time allowed
- ☐ I was nervous, and I think that is why I didn't do as well as I should have
- ☐ I wasn't nervous, but I didn't really understand how to perform some of the measurements

Figure 3. Question to assess student anxiety and results of how students rated their anxiety during the lab practical test.

Based on this study, we can conclude that both male and female students report a diverse level of previous experience (males report having more experience than females), but lack of experience does not predict how they will perform in the lab practical test. Students who are matched with a stronger partner do not perform as well in the lab practical. Anxiety does seem to be a factor in test performance. It's better for partners to be about the same skill level.

A Study of video tutorials and time in the lab

A study was conducted to determine the effectiveness of the video tutorials. Two sections of students who were enrolled in Circuit and Systems course during the winter quarter in 2008-2009 were compared. The students in section 1 (n=19) had the access to the video-tutorials before and during the lab. At the end of the class, 12 (63%) of the students responded to a survey to rate their preference for the video tutorials. The students in the second section (n=24) didn't have the access to the tutorials and were considered a baseline case.

In the first lab of the course, the students in section 1 were asked to watch the tutorials before they came to the class. During the lab, the instructor spent only 15 minutes reviewing the important points of the video tutorials. The instructor in the second section spent the first 45 minutes of the lab-time instructing to the group how to use the new equipment. The average time that the students spent working on the lab project is similar for the two sections (see Table 2). The video-based lab tutorials did save the instructor's time lecturing in the lab and as a result the students had more time to work on their lab project. In the second lab, the students in the first section watched the video-based tutorials before they came to the lab and the students in the second section did not. The instructors of both sections spent 15 minutes lecturing. The average time that the students of the first section spent working on the lab project is 15 minutes less than that of the second section. Table 2 summarizes the lab time for the first two lab periods in the two sections.

Labs	Section	Lecture Time (hours: mins)	Lab Time (hours: mins)	Total Time (hours: mins)
Lab 1	section 1	0:15	1:24	1:39
	Section 2	0:45	1:20	2:05
Lab 2	Section 1	0:15	1:02	1:17
	Section 2	0:15	1:17	1:32

Table 2 Average time spent in lab.

Overwhelmingly students who watched the videos agreed that they liked the video tutorials, the tutorials are more clear than the text-based instructions, the tutorials helped with their understanding and helped them to make efficient use of their lab time.

Based on this study, we can conclude that the uses of video lab tutorials are well received by the students and they can significantly shorten the time spent in the lab. A work in progress paper[9] discusses these results in further detail, however due to the small sample size we sought more data to assess the value of the lab tutorials.

A study of the role of video tutorials in conjunction with the lab

A total of 67 students were enrolled in a DC circuits course and had access to the lab tutorials but were not required to watch them. In addition to the "How-To" videos, an introductory video was created for half of the labs. Students were told that this introductory video will help them to prepare for lab by previewing what they will need to do in the lab, helping them to understand and complete the pre-lab calculations, and pointing out how to use new equipment. Each week students were asked to report how they prepared for lab, if they watched any of the lab introductory videos or "How-To" videos, if they read or skimmed the written lab procedure. Students were roughly split each week between reading the entire lab procedure and reading part of the lab procedure. Students appear to watch introductory videos when they are available as reported in Table 3. In the weeks that the lab introductory video is not available, some students are watching the "How-To" videos or the previous week's video to prepare.

	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 8
Read entire lab procedure	35%	50%	40%	48%	52%	48%	35%
Read/skimmed part of the lab procedure	58%	43%	58%	48%	43%	52%	55%
Did not read any of the lab procedure	8%	8%	3%	3%	5%	0%	10%
Watched entire lab video	81%	15%	64%	7%	33%	5%	53%
Watched par of lab video	15%	23%	5%	7%	17%	0%	283%
Did not watch any of the lab video	4%	63%	31%	86%	48%	96	21%

Table 3. Percent of students reading the lab manual and watching the video lab tutorials each week prior to attending lab. "How-To" videos are available each week, but lab introductory videos were available only during weeks 1, 3, 5, and 8. In week 7, the students completed the lab practical exam.

Near the end of the course, students were asked to complete a survey to assess their preference for the lab tutorials and how they felt the lab tutorials benefited them. A total of 55 (82%) students completed the survey. Table 4 summarizes how students felt the video tutorials benefited them. Confirming our earlier result, students on average agreed that they liked the video tutorials better than text-based instructions (3.45 out of a 5 point scale). Students also agreed that the tutorials helped them make efficient use of their lab time, and they helped them to gain confidence in lab measurement skills. There was no significant trend in their opinion associated with progressing time in the class.

	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 8
Video tutorials helped me to make efficient use of my lab time	3.77	3.89	4.07	4.00	4.08	4.13	4.00
Video tutorials improved my understanding more than the written material	3.73	3.78	3.71	3.90	4.00	4.00	3.96
Video tutorials are clearer than text-based instructions	3.45	3.72	3.32	3.70	3.69	4.13	3.72
I liked the video tutorials better than the text-based instructions	3.45	3.39	3.18	3.70	3.77	3.88	3.80
Video tutorials helped me to gain confidence in lab measurement skills	3.64	3.83	3.79	4.11	4.08	4.13	3.92

Table 4. Average rating of video tutorials. Scale: 5=strongly agree, 1=strongly disagree.

Students were asked to choose which resource would be their first choice in different lab learning situations. Based on their responses (Table 5), the students report that the best use of the lab manual is for preparing for lab each week, completing the pre-lab calculations, and completing the measurement tasks associated with the lab. The best use of the "How-To" videos are for learning how to use new equipment, and they still prefer that the instructor help them to debug problems in the lab. The fact that they still want the instructor help them debug problems in the lab may indicate that they have not developed independent skills. However, it could be that they have already exhausted all the other resources. The role of video tutorials for developing debugging skills is worth further study.

	Lab Manual	Your Lab Journal	"How-To"Video	Lab Introduction Video	Your Instructor
Prepare for lab each week	77%	6%	6%	8%	4%
Complete the pre-lab exercises	87%	8%	0%	2%	4%
Perform measurement tasks in the lab	60%	15%	17%	2%	6%
Learn how to use new equipment	26%	8%	44%	6%	17%
Answering analysis questions in the lab	67%	8%	8%	2%	15%
Debugging a problem in the lab	37%	9%	4%	8%	41%

Table 5. Percent of students choosing each resource as their first choice.

Conclusions

The video lab tutorials are, in general, perceived by students and instructors as useful tool in the lab. The visual nature of the aid was highlighted as the greatest strength of the tutorials. Students reported watching the videos before lab and during the lab even if not required to do so. Instructors were able to reduce the portion of in-class time spent instructing to a group, and overall time spent in the lab to complete the exercises was reduced when the tutorials were available. Students overwhelming reported that they liked the videos, the videos helped them to learn, and the videos helped them to make efficient use of their time in the lab. Students thought that the best use of the lab tutorials was to help them to learn how to use new equipment.

Based on our experience, video lab tutorials have the most value when used in conjunction with other resources in introductory lab courses, and seem to be most valuable to students with less previous experience and/or lower confidence in lab skills. Although students reported that they felt the videos helped them to become independent in the lab, further data is needed to determine if independence persists and if video tutorials help to prepare students for later courses.

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