

Worcester Polytechnic Institute

# Enhancing Physics Lab Multimedia

An Interactive Qualifying Project

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## **Abstract**

This project focused on enhancing lab use of multimedia to improve student understanding and comprehension of physics 1120 labs. Data was collected through observation of the lab setting and faculty reports. A series of videos were created illustrating the concepts of the lab, and added to the lab website. A survey was given to students that participated in lab sections and statistical analysis was performed on the data.

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## Introduction

The WPI Physics department wants to enhance physics labs in order to improve student understanding and comprehension of freshman physics labs. A good way to do this would be to take advantage of modern video and video editing technology. By adding instructional videos to the lab website, students would have easy access to a better understanding of the physics underlying the lab objectives, and common mistakes and misconceptions could be avoided. In order to have maximum impact on the students, it was important to select the right lab.

Choosing the right lab was an involved process. In order to record the results of our findings, one of the first four labs had to be focused on. Our team felt that we could be most helpful if we focused on a lab involving circuits, which are a difficult concept for most first year students. The only labs which met our criteria were the RC Discharge lab and the Linear vs. Nonlinear lab.

After thorough observation of both the RC Discharge and the Linear vs. Nonlinear labs our group decided to go with the former. The RC discharge lab struck us as a better choice for a variety of reasons. First, it is the lab where students are exposed to an actual circuit for the first time, as opposed to theoretical and conceptual models. Second, the students are under a time constraint to translate the schematic into a fully functional circuit. Finally, students are required to fully comprehend basic circuitry for later labs containing more complicated circuits.

## Background

Based on the information from conversations with Mr. Fred Hutson, the physics lab manager at Worcester Polytechnic Institute, students have had the most trouble with labs in the course PH1120: General Physics - Electricity & Magnetism. The labs that have given students the hardest time in this course were “Potential Difference & RC Discharge” as well as “Linear vs. Non-Linear Circuits.” Both labs required students to construct a circuit from a schematic, measure voltages and currents, and answer questions regarding the lab and how it relates to the theory taught in lecture.

We decided that the majority of our research needed to be done in the lab sessions with the students. The objective was to observe the sections and record what sorts of problems students encountered while trying to complete the lab assignment. Luckily, multiple sections of the each lab were easily made available over the course of two weeks, especially because a similar course with a slightly higher difficulty, PH1121: Principals of Physics - Electricity & Magnetism, had sessions of the same lab around the same time as PH1120. This meant that the observations recorded could be compared not only between different sections of the physics course, but also compared to a different course all-together. This also significantly increased the sample size of data that was able to be collected, increasing the accuracy of the data collected.

The research was carried out by attending physics labs during different sections. We employed two separate approaches during the observation periods. The first approach taken was considered passive research and focused primarily on interviewing the Teacher’s Assistants in the lab sections about what they have experienced in the past as far as common ‘trouble spots.’ Additionally, this method also involved observing the questions students would ask Teacher’s Assistants during the lab period.

The second approach taken was considered active research and involved looking for students who visibly appeared to be struggling or confused with the lab assignment. Once a student was spotted,

they were approached and asked about what they were having trouble understanding. If the student raised their hand, they were then observed while Teacher's Assistant attempted to resolve the issue, then the student was asked if the Teacher's Assistant's assistance was helpful or not.

After observing multiple lab sections of PH1120 and PH1121 over the course of the two weeks, utilizing the two approaches described above, the results were compiled, and were surprisingly similar across the board. It was noted in every section, regardless of the course or section, that a handful of students had trouble identifying the electrical components, building the circuit from a schematic, distinguishing between series and parallel wiring, understanding the concept of potential difference, and using some simple algebra in their calculations.

The difference between the frequencies of problems experienced in "Potential Difference & RC Discharge" compared to "Linear vs. Non-Linear Circuits" was also notable. The Potential Difference lab was the first lab (in both PH1120 and PH1121) in which students were asked to work with circuitry. This explained some of the difficulties that they encountered. This also explained the higher frequency of problems experienced during the Potential Difference Lab. By the time students began the Linear vs. Non-Linear lab, most are familiar with the lab equipment, and comfortable with the concepts required.

We found that a large number of incoming students had little or no experience with constructing a circuit. This explained the difficulty they faced when asked to build one from a schematic. Many of their questions and problems were resolved with a list identifying components and their function.

The problems faced by students during the labs we visited were narrowed down into two main groups, Components and Theory. The Component segments covered the equipment that students were actually working with in the lab, and the Theory segments gave students a

quick refresher about concepts learned in lecture. This defined the two approaches taken when the production phase began for the video segments.

During the labs students needed to be able to identify a component, as well as recognize its symbolic representation in a schematic. They also had to know how to interact with the component in order to wire it properly. It was also beneficial for the students to understand what the function of each component was. Without prior experience with circuitry, building a circuit from the schematic and completing the lab in the allotted 50 minutes becomes a difficult challenge for students.

Out of all the questions Teacher's Assistants received during these labs, a noticeable portion of questions were along the lines of "is this the component we are supposed to use?" or "what does this component look like?" On some occasions, several groups of students had to wait to get these questions answered by the TA, while the TA was answering the exact same questions for other groups. If there were a means to quickly convey what the component looked like in reality and in a schematic, as well as how to properly connect the component to a circuit, students would not have to waste time waiting for the TA. Also, students benefit from figuring out these issues on their own, as opposed to having the TA do the lab for them. We decided that each of the components would have its own short video segment. This way, a student could click on the video and understand everything they needed to know about a single component, in approximately 15-20 seconds.

The Theory segments had a slightly different approach from the Component segments. Many students did not fully grasp how to recognize when components were connected in series or parallel, which lead to several problems during labs. TAs spent a fair amount of time

answering the questions similar to “how do I wire in series/parallel?” and “is this wired correctly?” Again, students had to wait for the TA to finish answering the same question for other groups. If there were a video demonstrating the differences between series and parallel, then students would not have to waste time waiting idly for the TA. The real advantage here was, if the student figured out how to differentiate between the two, a core concept of circuitry was learned and understood. After we figured out the main areas of improvement, we had to figure out how to inform the students.



## Design Decisions

We decided to make video segments for both series and parallel wiring. This way, students that clicked on the appropriate video segment could quickly and easily learn about wiring. Each video segment had a supplementary video that played in the top left corner, and displayed a person wiring two resistors together. In the bottom left corner, under the supplementary video, a schematic of the components was drawn. Included on the right side of the segment were 3 short points of information about the voltage and current of the two separate wiring types.

Potential difference was also included under the Theory section of videos. Potential difference was an abstract concept that not all of the students understood. Unfortunately, it is one of the most fundamental concepts used in circuitry, so students that struggled with the concept performed poorly in the labs.

Since it was impossible to deliver any information that could be useful to students under the normal time limit, the limit for the potential difference segment was extended. Because there is no schematic or video that can be used to show what potential difference looks like, a different approach was taken as far as the layout was concerned. First, a textbook definition was displayed for the sake of educational purposes. However, since the textbook definition would not help most beginner students understand the concept, simple analogy shortly followed. The analogy compared several components of a simple circuit to a plumbing system: if a power supply is kind of like a water pump, electrical current flow is kind of like water

current flow, and a resistor is kind of like a valve that is partially closed than potential difference is kind of like the difference in water pressure at two points along the flow. This slide was included in an effort to help students get more of a grasp on the concept of potential difference

## Methodology

### Storyboarding

Initially, the group came together and explored various ways to convey the information needed for the specific lab. This section is rather important because without a simple layout or basic general design, communicating information can be difficult and inconsistent. The optimal design should be simple, easy to follow, and when viewed the user should be able find what they are looking for immediately.

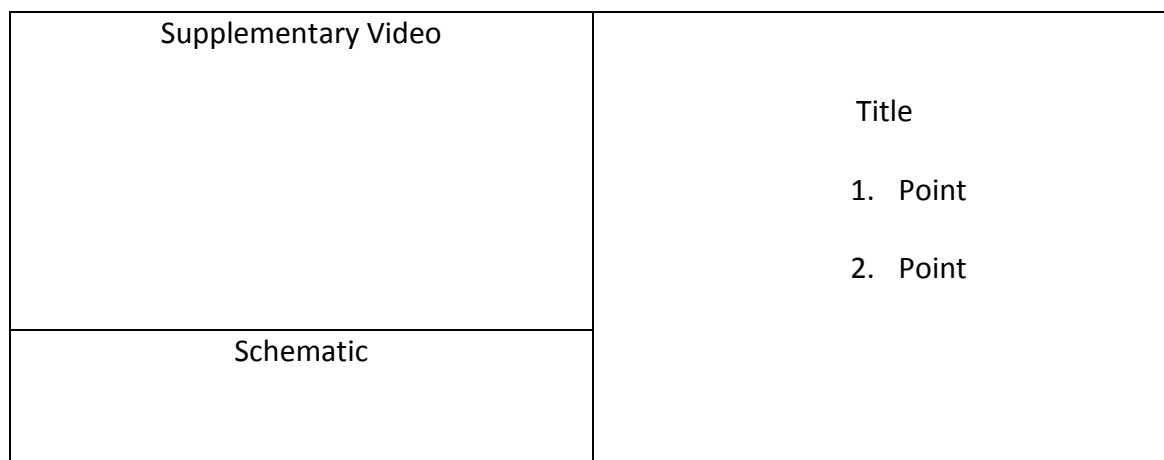


Fig 3.1 Design Layout used in this project

After that, the topics that were to be discussed through video were chosen. These topics included two categories, which are *Component Videos* and *Theory and Application Videos*. The chart below indicates all the categories and subcategories

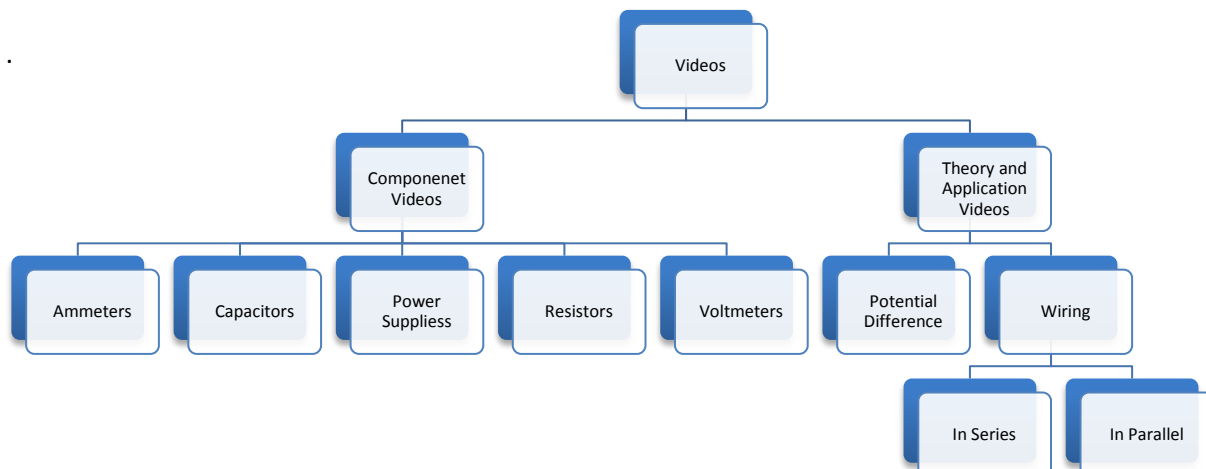


Figure 3.2 Hierarchies of Chosen Topics

## Script Writing

In this portion of the project, a script for every video was written. This included verbal speech, transitions, and written text. One thing that was taken into account for the script was the simplicity of language. Use of jargon was avoided and compensated for with easy definitions and analogies. The final script used in the videos is contained in Appendix 1.

## Creating Slide Layouts

Slides were created based on the design layout developed in the storyboarding portion of the methodology. The bullet points in the right portion of every slide were simple summaries of key information detailed in the video. Initially, multiple templates were created and discussed. After deciding on a final template, slides for all of the videos were developed in Apple's Keynote 2009 (



). Furthermore, transition effects were added to titles and points while recording voiceovers.

Copies of all the slides can be viewed in Appendix 2s.

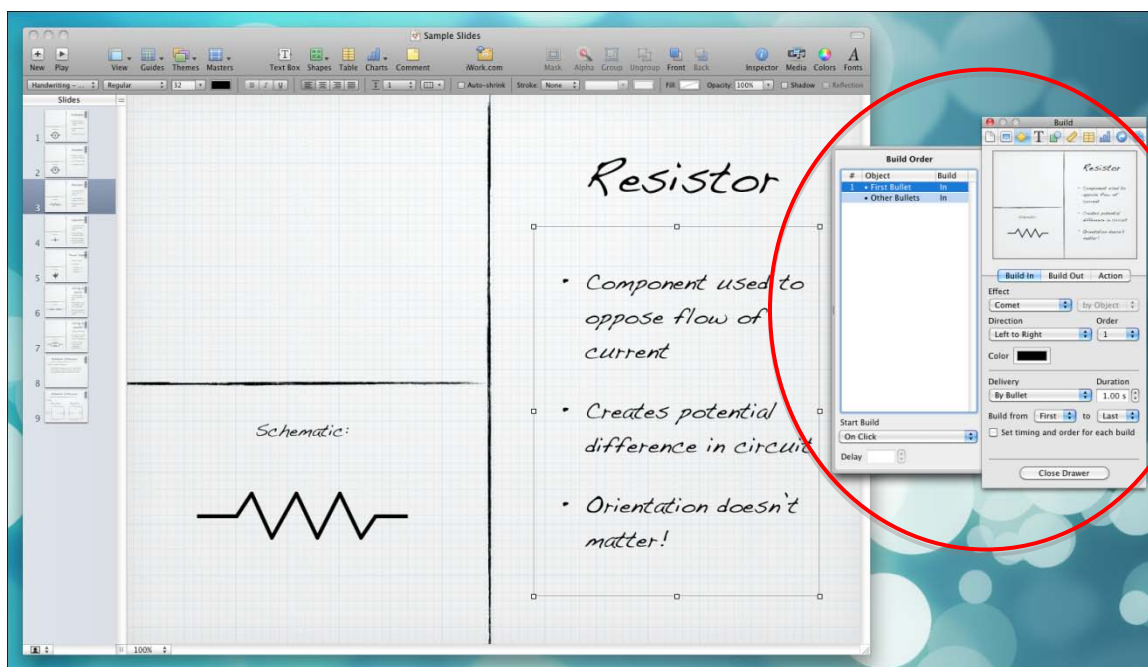


Figure 3.3 Screenshot of adding transition effects

### Shooting Supplementary Videos

Additional videos of lab equipment were shot to supplement the slides. A camera and tripod were borrowed from WPI's Academic Technology Center to be used in one of Olin Hall's lab rooms. The camera used for shooting video was a standard JVC HD camcorder with a built in hard drive. The tripod was used to secure the camera at the proper position and angle.

A few things were taken into consideration when shooting the videos. First of all, close attention was paid to the angle of the shot. We decided to shoot in a first person point of view. This would be optimal because it would give students a hands-on view of the equipment. Secondly, when connecting wires, the model's hands always had the wires and component above their hand. This was done to give the viewer an idea of what was going on as opposed to a blocked view. Finally, most of the equipment was set up in very similar way to the schematic to avoid confusion.

All of the scenes were shot multiple times in standard definition. High definition was avoided simply because of unnecessary size. Finally, the videos were exported from the camera onto a hard drive for later use.

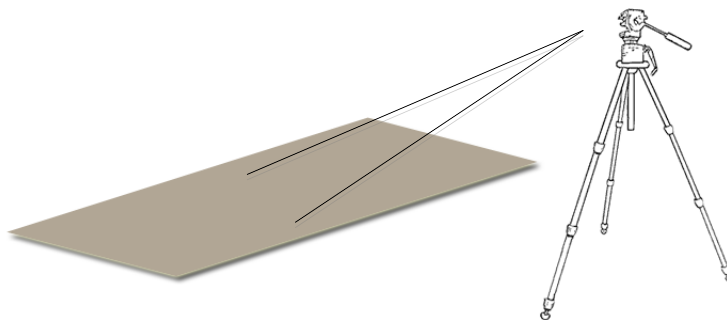


Figure 3.4 Camera Setup Apparatus

## Recording a voice over

This part of the project involved running through the slides created and recording a voiceover reading from the script. The program that was used for this project was Screenflow 2 for Mac OS X (



). A Logitech USB desktop microphone was connected to the computer to capture audio while the program was running.



Figure 3.5 Screenshot of Screenflow 2 settings

After the video was recorded, it was exported with the following settings:


Preset: Web – High

Encoding: H.264 high quality

Audio: ACC Stereo

## Post Editing and Exporting

This is the final step before the videos are completed. The program used in this section was

Adobe Premiere CS4 (  ). A new project file was created for each individual video. All related videos (Screen capture + supplementary videos) were then imported into the project file.

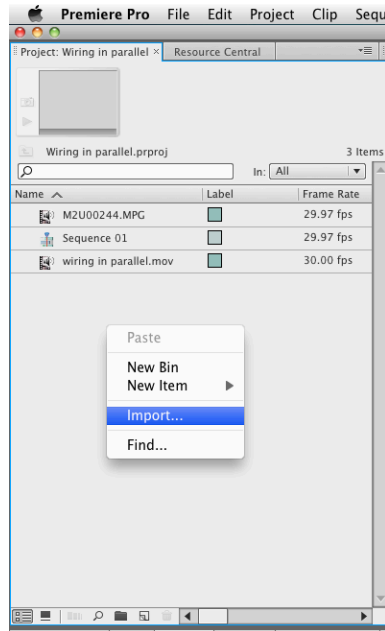
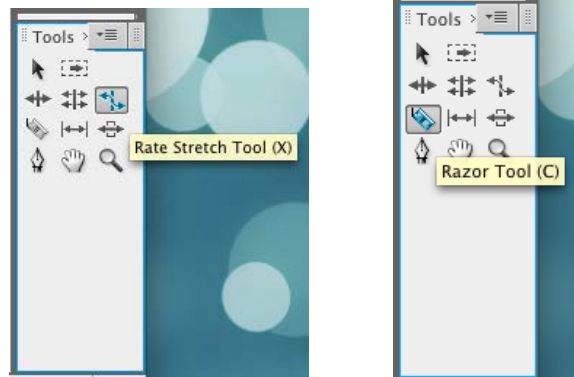


Figure 3.6 Screenshot of importing files into Premiere

These videos were then added to the timeline sequence and cropped accordingly using the “razor tool”.

Furthermore, all audio except the one from the screen capture was deleted. The next step would be to make the videos the same length using the “rate stretch tool”.



Figures 3.7 and 3.8 Screenshot of the “Razor” and “Rate Stretch” tools

Finally, the embedded video was resized and moved to the appropriate position on the frame. This was done by clicking on the video to be resized and moving one of the resizing squares on its edge. The figure below indicates where this is done.

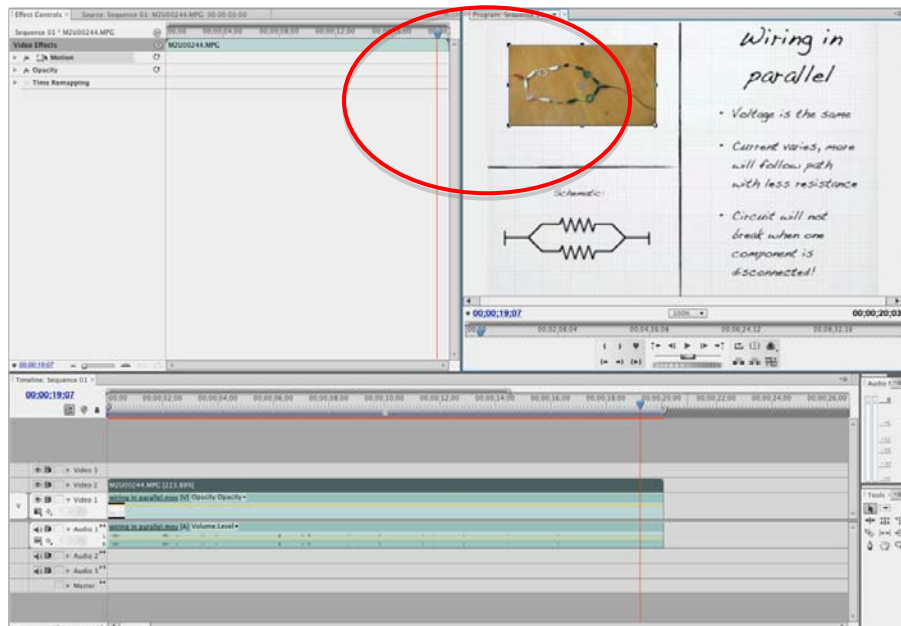


Figure 3.9 Screenshot of resizing videos in Premiere

The video is then exported using the following settings in the screenshot below:



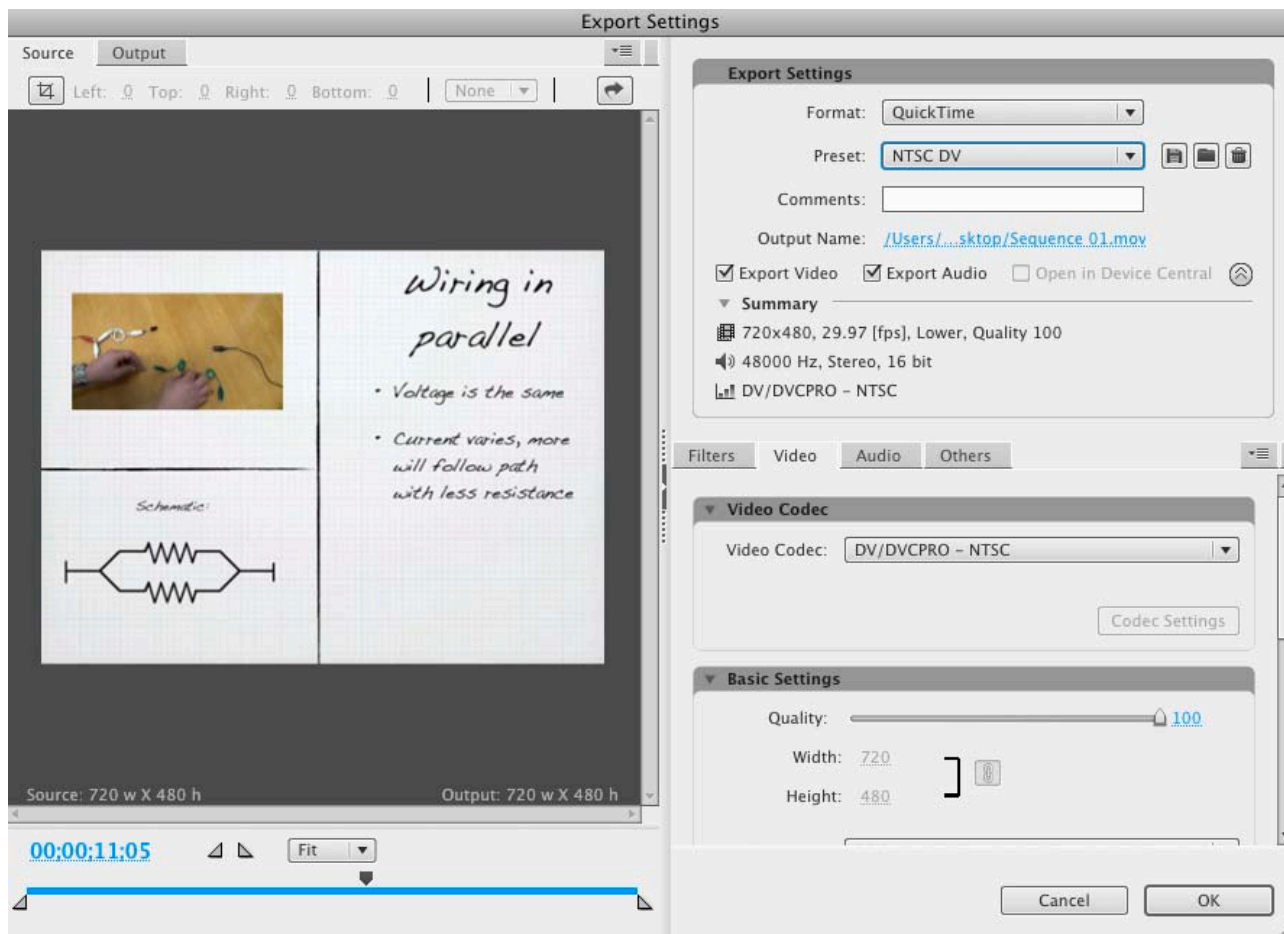


Figure 3.9 Screenshot of resizing videos in Premiere

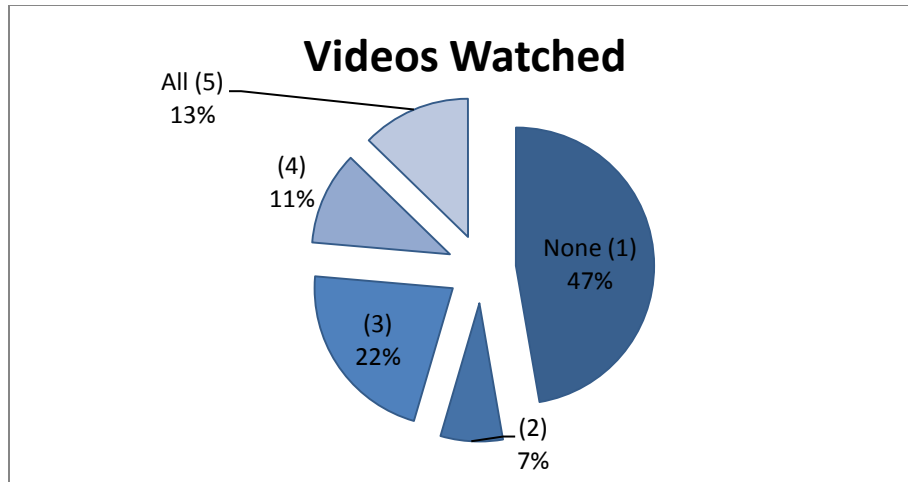
## Statistical Analysis and Conclusions

After uploading the videos to the physics server, and connecting them into the online physics lab, we were eager to see how our videos would affect the lab experience of the students. After uploading the videos to the lab, each one of us went to various lab sessions to gather feedback. The format of the survey was fairly simple, the students were asked to rank several categories of information on a scale from one to 5. Additionally there were 2 areas of blank space so that the students could give additional feedback should they desire. The survey that we gave each student is attached as Appendix 3. The purpose of the survey was to gather

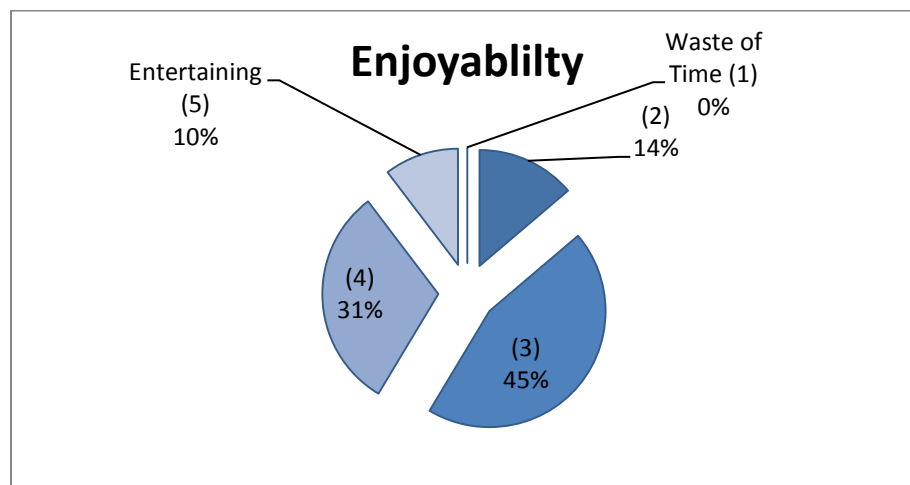
not only basic statistical information about the educational value of the videos, but to also see if the students enjoyed the videos and wanted to see more in the future. The full set of statistics gathered can be viewed in Appendix 4.

At first, due to some minor oversight on our part, students did not know that the videos were available. Since students were not informed about the videos, they did not watch the videos at first. Not wanting our work to go to waste, we went to additional labs and gathered more results. This time we made announcements at the beginning of the lab, and asked students to fill out the survey at the end of the lab period. We experienced similar results with this method, and knew that we had to rethink how we were acquiring our data.

We realized that the main reason that students were not going to the videos was because they didn't know where to find them. This time, instead of letting the students play hide and seek to find the videos they did not know existed, we started to take a much more hands on approach to gathering our data. Instead of making one blanket announcement at the start of the project, we decided to spend a few minutes with each lab group showing them how to access the videos on the web. This method was much more successful, as most of the feedback that came back said that students watched and enjoyed the videos.

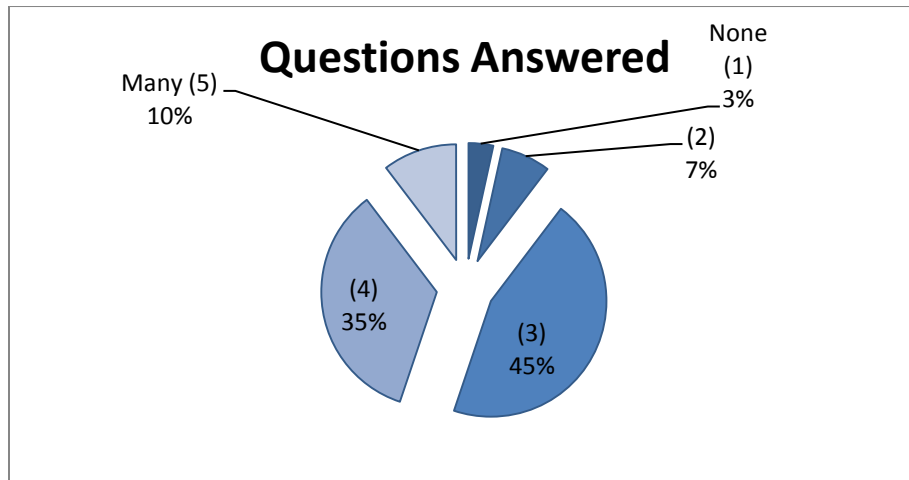


One of the goals of our project was to make labs more enjoyable. As illustrated by the graph below, students generally enjoyed multimedia additions, with over 84% of students finding the labs at least somewhat enjoyable. This means that through the creation of more lab multimedia has the potential to raise the students' opinions of labs.

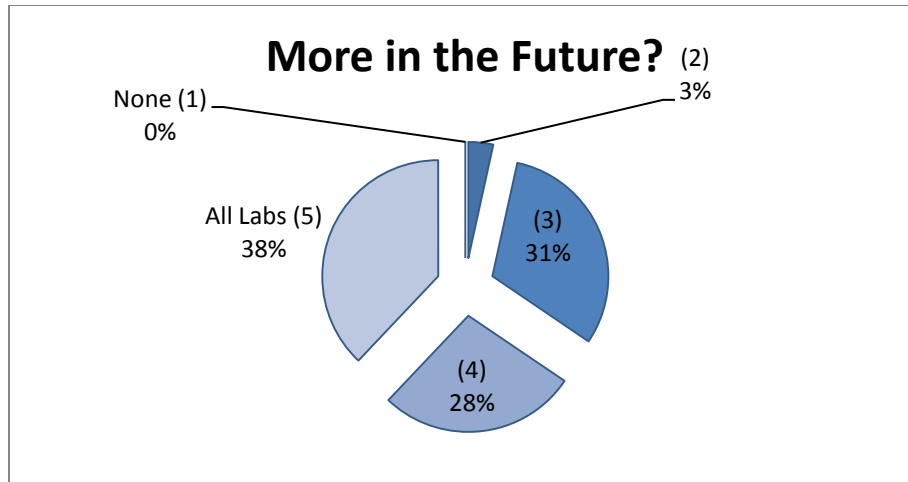


Another goal of the project was to answer questions that the students had. We found that over the course of the labs that we monitored, 86% of students that watched at least one

video had at least some questions answered by the videos. This meant that the design decisions we made while storyboarding the videos paid off, and our videos successfully communicated the basics of circuitry components and theory.



The final piece of data that we were focused on was whether the students wanted to see additional lab data in the future in a video format. We found the results from this part of the survey to be staggering. A full third of all the students that watched at least one video would like to see similar multimedia in all physics labs. Additionally, over 90% of students want to see similar multimedia in at least some physics labs. We asked the students and they told us quite clearly, add more media.



A number of conclusions about the success of lab multimedia were drawn from these reflections. First of all, students responded positively to the multimedia addition to the lab. This meant that in the future more and more aspects of labs could be multimedia driven. Another conclusion we reached was that the educational objectives of the videos were reached, and our goal of answering the simple questions of students was met. This freed up the teaching assistant for more difficult and situational questions. This meant that in the future, lab sections could be larger if there were more multimedia options built into the lab interface. In all, introducing physics multimedia to labs was a successful endeavor, and this aspect of educational technology has plenty of room to grow.

## Appendix 1: Script

### Voltmeter

[The scene starts with an image of a schematic of a voltmeter in the top left, a photograph of a voltmeter in the bottom left, and black space for bullet points on the right hand side]

voiceover : A voltmeter is an instrument used for measuring the electrical potential difference, in volts, between two points in an electric circuit. Ideally voltmeters have infinite resistance, and are connected to circuits in parallel.

### Ammeter

[The scene starts with an image of a schematic of an ammeter in the top left, a photograph of an ammeter in the bottom left, and black space for bullet points on the right hand side]

A voiceover says: an ammeter is an instrument used to measure the electric current in a circuit, in amperes. Ideally, ammeters have no resistance, and are connected to a circuit in series.

### Resistor

[The scene starts with an image of a schematic of a resistor in the top left, a video of a resistor in the bottom left, and black space for bullet points on the right hand side]

A voiceover says: A resistor is a device used in an electrical circuit to oppose the flow of an electric current. This creates a potential difference in a circuit. It does not matter what orientation a resistor is connected in, the results will be the same.

### Capacitor

[The scene starts with an image of a schematic of a capacitor in the top left, a photograph of a capacitor in the bottom left, and black space for bullet points on the right hand side]

A voiceover says: A capacitor is a component used in an electrical circuit to store and discharge energy. Capacitors are a polar component, which means the orientation of a capacitor in a circuit matters. The amount of energy stored in a capacitor, known as the capacitance, is measured in farads.

### Wiring in Series

[The scene starts with an image of a schematic of a circuit, wired in series, on the bottom left, a supplementary video of the same circuit on the bottom left, and black space for bullet points on the right hand side]

Voiceover: Wiring in series means the current through each of the components is the same, and the voltage across all the components is the sum of the voltages across each component. One thing to keep in mind when wiring in series is that if one component becomes disconnected, the result would be an open circuit, and the flow of current would stop.

## Wiring in Parallel

[The scene starts with an image of a schematic of a circuit, wired in parallel, on the bottom left, a supplementary video of the same circuit on the top left, and black space for bullet points on the right hand side]

Voiceover: Wiring in parallel means the voltage across each of the components is the same; however the current passing through each component is different. One thing to keep in mind is that current will want to go where there is less resistance. If one component disconnects, then it would not stop the flow of current throughout the whole circuit.

## Potential Difference

[“What is Potential Difference?” appears on the board]

[Begin Voiceover] What is Potential Difference? [pause]




Potential difference is the potential energy per unit of charge that is associated with a static electric field. It is a scalar quantity, typically measured in volts. [pause]

Well that was a little thick, how about an analogy?

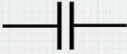


[The slide transitions two diagrams, one with a circuit and the other with a plumbing system]

One way to explain potential difference would be to think of a circuit as a series of pipes. The potential difference from one point to another would correspond to the difference in water pressure. The power supply can be thought of as a pump. At the start of the pump the water flow would be the greatest and would decrease as the water flows through the pipes; the larger the pressure difference the greater the flow. Resistors in a circuit can be thought of as valves that slow down the water flow or increase the potential difference.

## Appendix 2: Video Layouts

Voltmeter	<p>Schematic:</p> 	<h3>Voltmeter</h3> <ul style="list-style-type: none"><li>• Measures electric potential difference, in Volts.</li><li>• Infinite resistance (ideal)</li><li>• Connected in parallel</li></ul>
Ammeter	<p>Schematic:</p> 	<h3>Ammeter</h3> <ul style="list-style-type: none"><li>• Measures electric current, in Amperes.</li><li>• No resistance (ideal)</li><li>• Connected in series</li></ul>
Resistor	<p>Schematic:</p> 	<h3>Resistor</h3> <ul style="list-style-type: none"><li>• Component used to oppose flow of current</li><li>• Creates potential difference in circuit</li><li>• Orientation doesn't matter!</li></ul>



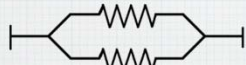
<p>Capacitor</p>	<p>Schematic:</p> 	<h3>Capacitor</h3> <ul style="list-style-type: none"> <li>• Component used to store/discharge energy</li> <li>• Polar component, orientation matters!</li> <li>• Amount of energy stored (capacitance) measured in farads.</li> </ul>
<p>Power Supply</p>	<p>Schematic:</p> 	<h3>Power Supply</h3> <ul style="list-style-type: none"> <li>• Supplies power</li> <li>• 3 Terminals: <ul style="list-style-type: none"> <li>• Positive (+)</li> <li>• Neutral (-)</li> <li>• Ground (⊥)</li> </ul> </li> </ul>
<p>Wiring in Series</p>	<p>Schematic:</p> 	<h3>Wiring in Series</h3> <ul style="list-style-type: none"> <li>• Current through each component is equal</li> <li>• Total voltage = sum of voltages across each component</li> <li>• If one component disconnects, circuit breaks</li> </ul>

Wiring in Parallel

### Wiring in parallel

- Voltage is the same
- Current varies, more will follow path with less resistance
- Circuit will not break when one component is disconnected!

Schematic:



The schematic shows two resistors connected in parallel between two common terminals. Each resistor is represented by a zigzag line.

Potential Difference

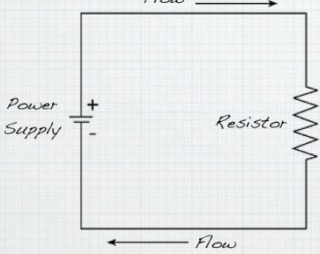
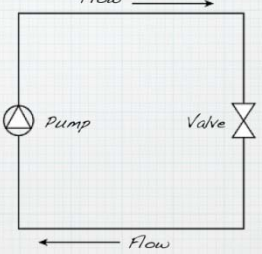
### Potential Difference

- What is potential difference?

The potential energy per unit of charge that is associated with a static electric field. It is a scalar quantity, typically measured in volts.

### Potential Difference

Analogy:

Electric Circuit	Water Circuit
 <p>The diagram shows a square loop representing an electric circuit. On the left side, there is a power supply symbol with a '+' sign at the top and a '-' sign at the bottom. On the right side, there is a resistor symbol (zigzag line). Arrows indicate the direction of flow: an arrow at the top points to the right, and an arrow at the bottom points to the left.</p>	 <p>The diagram shows a square loop representing a water circuit. On the left side, there is a pump symbol (a circle with a triangle inside). On the right side, there is a valve symbol (two triangles meeting at a point). Arrows indicate the direction of flow: an arrow at the top points to the right, and an arrow at the bottom points to the left.</p>

## Appendix 3: Survey

### Post Lab Questionnaire

Lab Section:

How would you rate your prior experience with circuitry?

(None) (Some) (Mastery)

1 2 3 4 5

Did you watch the videos?

(None) (Some) (All)

1 2 3 4 5

If none, Why not?

Did the videos answer any questions you had about circuitry?

(None) (Some) (Many)

1 2 3 4 5

Did the videos make the lab more enjoyable?

(Waste of time) (Entertaining and Educational)

1 2 3 4 5

Would you like to see more labs with video guides?

(None) (Some) (All)

1 2 3 4 5

Any recommendations for improvement?

## Appendix 4: Data

Lab Section:	Did you watch them?	Answer Questions?	Enjoyable?	More in future?
1	1			
1	1			
1	2	2	3	3
1	1			
1	5	2	2	5
1	1			
1	1			
1	1			
1	1			
1	1			
4	5	4	4	5
4	3	3	3	4
4	3	4	3	3
4	1			
4	1			
4	3	1	4	5
4	1			
4	3	3	3	2
4	3	3	3	4
4	3	3	4	3
4	3	3	3	3
4	3	3	2	4
4	5	5	4	5
7	1			
7	1			
7	1			
7	1			
7	1			
7	1			
7	1			
7	1			
7	1			
7	1			
7	1			
7	1			
7	1			
7	1			
7	1			
7	3	4	2	3
7	1			
3	5	3	5	5

3	4	5	5	5
3	1			
3	4	3	4	4
3	4	4	4	5
3	2	4	3	3
3	2	3	2	3
3	2	4	3	4
3	4	4	4	5
3	5	4	5	5
3	3	3	3	5
3	3	5	3	3
3	3	4	3	4
3	4	3	4	5
3	4	4	4	4
3	5	3	3	3
3	5	3	3	4
Count:	55	29	29	29
mean	2.40	3.41	3.38	4
median	2	3	3	4
mode	1	3	3	5

Frequency 1	26	1	0	0
Frequency 2	4	2	4	1
Frequency 3	12	13	13	9
Frequency4	6	10	9	8
Frequency 5	7	3	3	11