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Title

Investigating the Potential of Interactive Digital Learning Tools

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Investigating the Potential of Interactive Digital Learning Tools

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Abstract

The purpose of this study is to compare the efficacy of two learning methods: the traditional slideshow method of disseminating information (control group) versus the usage of guided digital simulations (experimental group). Two hypotheses are proposed: *interactivity hypothesis* and *distraction hypothesis*. The distraction hypothesis predicts that the control group will learn better while the interactivity hypothesis predicts that the experimental group will learn better. The results showed no significant difference between the groups on transfer-scores, and the control group rated the learning activity as more enjoyable and easier than did the experimental group. The results partially support the distraction hypothesis.

Introduction

Objective and Rationale

Over the past 200 years, the education system and methods employed by institutions to train students have evolved concurrently with the technological revolution. As a result, many of the educational tools employed by schools and universities tend to rely heavily on the use of technology. One of the most common methods of teaching is the traditional lecture method, in which instructors often use digital media in the form of slideshow presentations. However, recent findings in the field of educational psychology demonstrate alternative methods of employing digital media to disseminate academic information to students, using methods such as games and digital simulations (Mayer & Moreno, 2001; Mayer, 2014a).

The purpose of this study is to investigate interactive methods of instruction, specifically the efficacy of hands-on, guided digital simulations, compared to traditional passive slideshow methods of instruction. According to the interactivity theory, the interactive nature of guided simulations, compared to the passive nature of slideshows, allows students to learn information more deeply and enjoyably. On the other hand, according to distraction theory, the hands-on approach could introduce distraction in the form of extraneous processing and cognitive load, which could take away from the learning experience. In this study, participants were given a lesson on electrical circuits and Ohm's law. Two groups were randomly administered one of the two different methods of instruction compared in this study. Though both groups received the same information, the experimental group was administered the hands-on digital simulation, whereas the control group received a slideshow. In order to test for learning outcome, a transfer test was administered, containing questions pertaining to Ohm's law.

Literature Review

The use of multimedia instruction has potential to help students better engage with academic material and learn new information (Honey & Hilton, 2011; Mayer, 2009, 2014b). For example, a study done by Moreno and Mayer (2001) showed that introduction of interactive pedagogical agents can promote meaningful learning in lessons using multimedia. In some ways, a guided digital simulation can function as an interactive pedagogical agent by inviting the learner to more actively participate. According to a meta-analysis done by Vogel and Vogel (2006) about computer games and interactive simulations for learning, "Across people and situations, games and interactive simulations are more dominant for cognitive gain outcomes." Thus, research is needed to determine whether digital simulations can be used in a similar way as games, resulting in similar cognitive and learning outcomes. However, using digital media without any guidance might not be an effective method of learning.

Results from a previous study done by Mayer and Moreno (2005) regarding the effects of guidance in a digital media learning study "support the appropriate use of guidance and reflection for interactive multimedia games." This study also showed that interactivity with the proposed learning material is the factor that improves learning and retention rates. In addition, application of the self-explanation principle—asking students to explain the material to themselves—in the guided simulation also helped students better retain information (Johnson & Mayer, 2010).

The competing theory in this study is the distraction theory, which proposes that due to additional extraneous processing, a type of "cognitive processing that does not support the learning objective and is caused by poor instructional design" (Mayer, 2010), the guided simulation will detract from the learning objective. This negative effect on learning may occur because the guided simulation would require a higher cognitive cost, including using a new interface, that could distract the learner from the core material.

Theory and Predictions

Based on the literature review in the previous section, the interactivity hypothesis proposed in this study argues that due to an active and hands-on approach to learning, individuals who attempt to learn via guided digital simulations will retain more information, indicating a better learning experience, and enjoy the activity more than those who learn passively through a slideshow. On the other hand, the distraction hypothesis proposed in this study argues that due to an increase in extraneous processing and cognitive load, the participants who learn through the guided digital simulation will retain less information, indicating a worse learning experience, and provide less favorable ratings of the activity than those who learn passively through a slideshow. In order to test both hypotheses, participants were randomly assigned to one of two groups: the digital simulation group (experimental) or the slideshow presentation group (control). The subject material was Ohm's law and the simple workings of electrical circuits. The digital simulation group was given a worksheet that not only acted as an instructional guide to direct the participants in building and measuring circuits, but also contained prompts for participants to predict what would happen to the flow of the circuit prior to creating it, measure the change in current, and reflect on why they think the flow changed. On the other hand, the control group was only given a slideshow presentation that contained pre-made screen-recorded videos of the researcher constructing the circuits using the same instructional tools and process that the guided digital simulation would use, followed by slides summarizing the videos in words. After the learning activity, both groups were administered a transfer test to measure how well they had learned the information presented in the activities, along with a self-rating questionnaire.

Method

Participants and Design

The participants were 69 undergraduate students recruited from the psychology subject pool at the University of California, Santa Barbara. The students were between the ages of 18 and 25 (M = 18.5, SD = 1.12), studying in various majors, but the majority of participants were psychology, biopsychology, or psychological and brain sciences majors. There were 19 men and 50 women. On average, participants showed low prior knowledge about circuitry and physics based on a participant questionnaire (described below). This study was conducted using a between-subjects design with two groups: a control group (n = 34, 11 men and 23 women) and an experimental group (n = 35, 8 men and 27 women).

Materials and Apparatus

Paper materials

The paper materials consisted of an informed consent form, a participant questionnaire, a transfer test, and a post-questionnaire. The participant questionnaire contained questions about the participant's age, gender, major, and year in school, along with a prior-knowledge assessment. A prior-knowledge score was obtained by assigning values to each question and adding up the values. The sum of values obtained from questions 1–6 yielded a subjective prior-knowledge score, intended to create an indication of each participant's prior knowledge of the learning material involved in this study.

The transfer test contained eight questions in the form of eight slides, each with two circuits displayed (see Figure 1). In order to judge the amount of information the participant learned, a transfer score (ranging from 0 to 8) was determined by adding up all of the correct answers in the transfer test. The set of eight test items is shown in Appendix A.

The post-questionnaire was used to solicit each participant's opinions about their learning experience. It contained five questions in which participants were asked to give ratings on a 5point scale for the following items: (1) How much did you enjoy this learning process (1 – not at all, 5 - loving it)? (2) Would you do a similar activity again (1 - not at all, 5 - definitely)? (3) During the lessons, my mental effort was (1 - 0% mental effort, 5 - 100% mental effort) (4) How difficult was the lesson (1 - easy and 5 - impossible)? (5) How easy was it for you to learn the material (1 - easy and 5 - impossible)?

Instructional materials

The instructional materials used in this study consisted of a slideshow presentation (for the control group), a guided worksheet (for the experimental group), and a virtual Phet AC/DC Circuit Kit Lab Simulation created at the University of Colorado, Boulder (also for the experimental group; https://phet.colorado.edu/en/simulation/circuitconstruction-kit-dc-virtual-lab).

The experimental group subjects were given the digital simulation and a guided worksheet that contained instructions on how to construct five circuits using the Phet AC/DC Circuit Kit Lab Simulation (see Figure 2). The exercises were designed to teach participants how the flow of electricity in a circuit is affected when batteries and resistors are added to the circuit in series or parallel, based on Ohm’s Law. Each exercise also prompted the participant to measure the change in current (amps) using an ammeter. The virtual lab simulation and the experimental group worksheet administered simultaneously created a guided simulation. The set of worksheets is shown in Appendix B.

The control group subjects were given a PowerPoint presentation consisting of eight informational slides explaining how the flow of electricity in a circuit is affected when batteries and resistors are added to the circuit in series or parallel. Before each slide, a video was shown of the circuit being constructed in the PHET simulation (see Figure 3), which was followed by a slide explaining in words the concept covered in the video (see Figure 4). The videos were screen recordings (captured by the researcher) of the circuits being constructed on the lab simulation site, guided directly by the instructions in the experimental group worksheet. The screen-recording program “Movavi Screen Recorder Studio 10” was used to create the videos displayed in the slideshow. The set of eight slides is shown in Appendix C.

The purpose of the instructional material was to teach participants about eight different rules regarding circuits, based on Ohm’s Law: (1) When a battery is added in series, the flow of electrons (amps) increases. (2) When a battery is added in parallel, the flow of electrons (amps) stays the same. (3) When a resistor is added in series, the flow of electrons (amps) decreases. (4) When a resistor is added in parallel, the flow of electrons (amps) increases. (5) When a battery is removed from series, the flow of electrons (amps) decreases. (6) When a battery is removed from parallel, the flow of electrons (amps) stays the same. (7) When a resistor is removed from series, the flow of electrons (amps) increases. (8) When a resistor is removed from parallel, the flow of electrons (amps) decreases.

The apparatus consisted of three 21-inch iMac computers, each including a keyboard and mouse.

Procedure

Participants were tested in groups of three, with each participant seated in a separate cubicle consisting of two opaque walls on either side, with a 21-inch iMac computer, a keyboard, and mouse on the desk in front of them. Each group of participants was randomly assigned to either the control group or the experimental group. After participants signed the informed consent form, they were prompted to complete and turn in the participant questionnaire. Next, the slideshow was presented to the control group. Each participant viewed the slideshow independently on separate computers. Participants were asked to study the videos in the slides as well as the text explaining each video in subsequent slides. The experimental group was prompted to open the simulation and follow the instructions on the guided worksheet in order to construct the circuits. Although the groups were timed, they were instructed to take as much time as needed to learn the information and finish the activities.

After the slideshow or worksheet was completed, the activity materials were closed, and the participants were given the transfer test. Once participants completed the transfer test, they were administered the post-questionnaire. The control group took an average of 5 to 10 minutes to complete the slideshow, while the experimental group took an average of 15 to 25 minutes to complete the guided simulation and worksheet. It took the participants an average of 5 to 10 minutes to complete the transfer test. IRB approval was obtained and guidelines for treatment of human subjects were followed throughout the experiment.

Results

Do the Groups Differ on Basic Characteristics?

A preliminary step was to determine whether the groups were equivalent on basic characteristics. The mean ages of participants in the experimental group ($M = 18.86$, $SD = 1.38$) did not differ significantly from the mean ages of participants in the control group ($M = 18.68$, $SD = 0.88$; $t(67) = 0.65$, $p = 0.52$). The proportion of men and women in the experimental group (8 males, 27 females) was not significantly different than the proportion of men and women in the control group (11 males, 23 females) based on a Fisher's exact test ($p = 0.43$). The mean prior-knowledge score for the experimental group (*M* = 5.83, *SD* = 2.96) was significantly greater than the mean prior-knowledge score for the control group (*M* = 7.76, *SD* = 4.62; *t*(67) = -2.08, *p* = 0.04, *d* = 0.37). We concluded that the groups were equivalent on basic characteristics except for prior knowledge, so we included prior knowledge as a covariate in subsequent analyses.

Do the Groups Differ on Learning Outcomes?

According to the interactivity hypothesis, the experimental group should score higher on the transfer test than the control group; according to the distraction hypothesis, the control group should score higher on the transfer test than the experimental group. Table 1 shows the means and standard deviations for the two groups on the transfer test. A t-test showed that the groups did not differ significantly on transfer test scores (*t*(67) = -1.03, *p* = 0.31, *d* = 0.25). In order to compensate for pre-existing differences in prior-knowledge score, we conducted an analysis of covariance on transfer score with prior knowledge as a covariate and control or experimental group as the between-subjects factor. The ANCOVA statistical analysis (analysis of covariance) showed that the two groups did not differ significantly on transfer score (*F*(66) = 0.36, *p* = 0.54), indicating that the differences found in prior knowledge did not affect our results. We concluded that the predictions of the interactivity hypothesis were not supported.

Did the Groups Differ on Self-Reported Measures?

According to the interactivity hypothesis, the experimental group should produce more favorable ratings on the post-questionnaire than the control group, but according to the distraction hypothesis, the opposite should hold true. Table 2 shows the mean ratings and standard deviations for the two groups on each of the five post-questionnaire items. The first question asked the participant to rate how much they enjoyed learning from the activity. Results from a t-test showed that the control group enjoyed learning from the activity more than the experimental group (*t*(67) = -2.02, *p* = 0.03, *d* = 0.53). The second question asked the participant to rate how likely they would be to do similar activities in the future. Results from a t-test showed that the groups did not differ significantly in their likelihood to do similar activities in the future (*t*(67) = -1.25, *p* = 0.22, *d* = 0.31). The third question asked the participant to rate how well they thought the activity helped them learn. Results from a t-test showed that the groups did not differ significantly in how well they thought the activity helped them learn (*t*(67) = -1.75, *p* = 0.09, *d* = 0.42). The fourth question assessed the participant's level of mental effort during the activity. Results from a t-test showed that the groups did not differ significantly in their level of mental effort during the activity (*t*(67) = 0.83, *p* = 0.41, *d* = 0.20). The fifth question asked the participant to rate the difficulty of the activity. Results from a t-test showed that the control group thought that the learning activity was easier than did the experimental group ($t(67) = 2.98$, $p = 0.00$, $d = 0.72$). Overall, post-questionnaire test results showed that the control group perceived their lesson to be easier, while the experimental group perceived their lesson to be more difficult. Additionally, the control group enjoyed the lesson more than the experimental group did.

Discussion

Empirical Contributions

The results obtained do not provide statistically significant evidence that a guided digital learning simulation is a more effective learning tool than the traditional slideshow experience. In addition, results showed that the control group found the task to be easier and more enjoyable. One possible explanation for these results is that the control group is administered a passive learning experience that requires less time and effort than the experimental group's activity, making it a more enjoyable and easier experience.

Theoretical Implications

The results provide partial support for the distraction hypothesis. Based on the predictions from the interactivity hypothesis, the experimental group should have performed better on the transfer test; however, the control group performed slightly better on the test than the experimental group did, albeit at a nonsignificant level. In turn, the results of the self-report ratings support the distraction hypothesis and suggest that the experimental group may have been distracted by the complexities of the media apparatus.

The argument can be made that the high level of initial cognitive cost in learning digital protocol prior to accessing the learning material may introduce cognitive load, possibly decreasing the efficacy of the digital learning activity (Sweller, Ayers, & Kalyuga, 2011). The cognitive load, which would be introduced by the hands-on digital simulation and guided activity, is absent in the traditional slideshow learning method, which could be the reason for the improved ratings and performance of the control group. The cognitive cost associated with learning the digital protocol during this experiment could have been mitigated with a digital pretraining session for the experimental group, so the participants would be familiar with the apparatus prior to learning the actual instructional material contained in the guided simulation.

Practical Implications

Although the results from this study are inconclusive, the use of multimedia and games in education could be impactful in making the learning experience more interesting and attractive to students. Due to the passive nature of learning from a slideshow presentation during a lecture, many students are often distracted by their own electronic devices, like mobile phones and computers. As a result, students may not engage with the information in this traditional manner of learning. By introducing effective hands-on multimedia learning strategies, the education system can optimize the educational experience for students by actively engaging them in learning. Research, however, is needed to determine how to design effective interactive simulations.

Limitations and Future Directions

Since the transfer test was administered immediately after the learning task was completed, it is possible that the control group invoked working memory, rather than long-term memory, to complete the transfer test, which would not be a true measure of retained learning. Administration of a ten-minute distraction task to both groups after completing the learning activity could prompt participants to clear the caches of their working memory, therefore making the transfer test a better measure of learning outcome. Due to time limitations, we were unable to implement these methods in this study. In addition, the time frame of this research project limited the number of subjects that were able to participate.

Based on the results and explanations of this study, several relevant research ideas could be explored. One major concept that could be researched is the amount of cognitive load required to learn novel educational digital media protocols. For example, assessing how much cognitive effort is required to learn the digital protocols in this study prior to the lesson material itself might reveal complexities of the digital protocols that may be contributing to the distraction. Studying methods of optimizing guided lab simulations may allow students to learn a variety of topics in further depth.

Conclusion

While the results of this study did not prove the interactivity hypothesis, it could be due to the various limitations of the study; therefore, additional investigation into the field of handson multimedia learning is necessary to yield more conclusive results. Digital media has the potential to revolutionize the learning process by creating immersive learning experiences that could help students deeply learn information in a practical manner while truly enjoying the process, thus enabling students to excel in learning throughout their lives.

About the Author

Chinmay Surpur is a graduating senior with an honors degree in Biopsychology as well as departmental honors in the department of Psychology and Brain Sciences for the completion of his senior thesis project. Chinmay is extremely passionate about research, especially in the field of psychology. He is hoping to pursue a PhD degree in Clinical Psychology with an emphasis on Addiction. Aside from conducting research, Chinmay loves to listen to hip-hop, watch a good series on Netflix, or work on his various side projects.

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Table 1

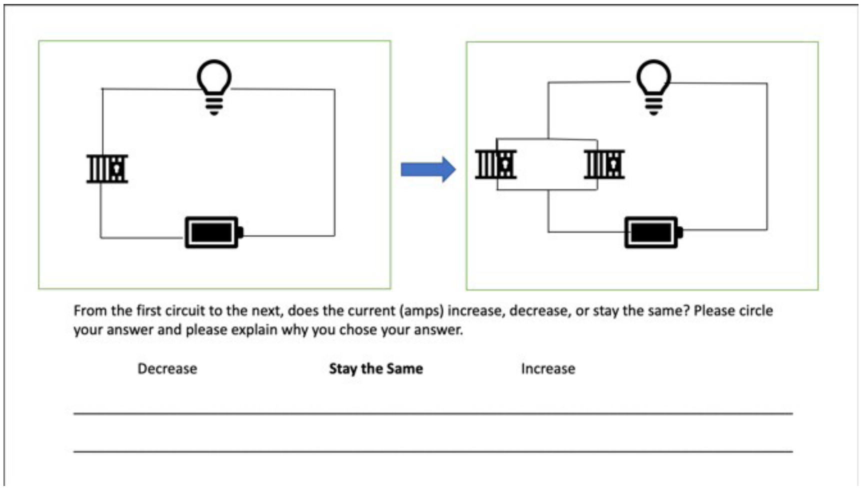
Mean Transfer Scores (and Standard Deviations) for Experimental and Control Groups

Group	**M**	**SD**
Experimental	5.03	1.38
Control	5.35	1.22

Table 2

Mean Ratings (and Standard Deviations) on Five Items for the Experimental and Control Groups

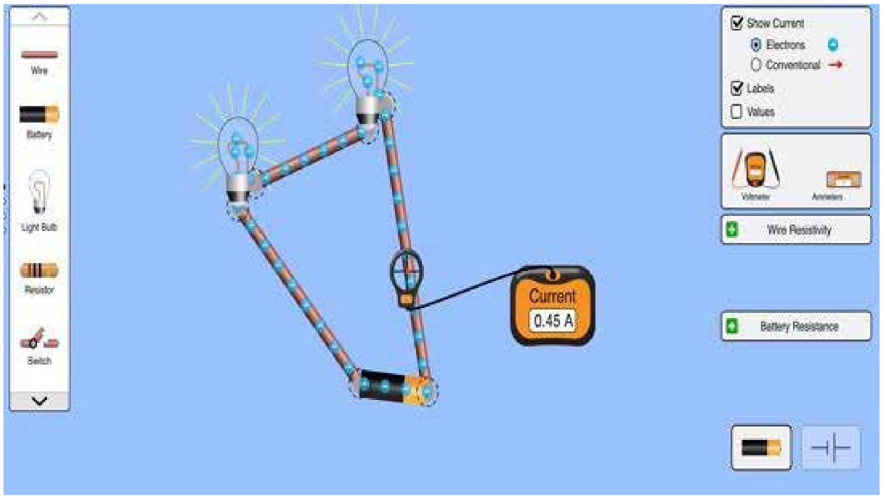
Question	**Experimental Group**		**Control Group**	
	M	SD	M	SD
Question 1 (enjoy)	3.78	0.73	4.18	0.80
Question 2 (future)	3.74	0.78	4.00	0.92
Question 3 (helped)	4.11	0.83	4.47	0.86
Question 4 (effort)	3.37	0.81	3.21	0.84
Question 5 (difficulty)	2.74	0.74	2.18	0.83



From the first circuit to the next, does the current (amps) increase, decrease, or stay the same? Please circle your answer and please explain why you chose your answer.

Decrease **Stay the Same** Increase

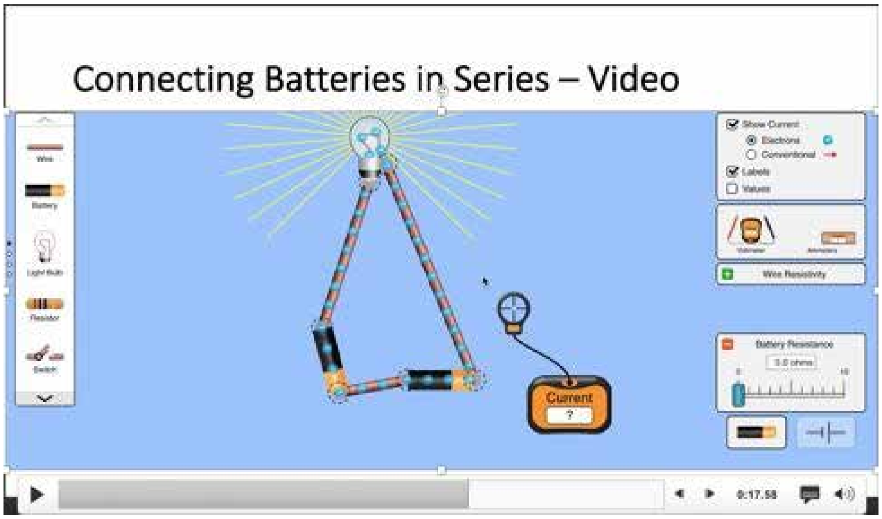
Figure 1. Transfer-of-training test sample question.



☑ Show Current
● Electrons
○ Conventional
☑ Labels
☐ Values

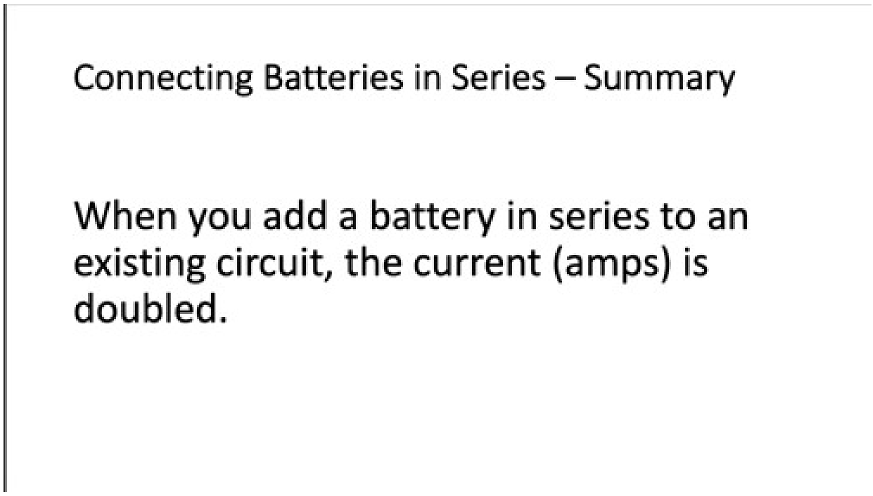
Current 0.45 A

Figure 2. Circuit construction exercise sample.



Connecting Batteries in Series – Video

Figure 3. Instructional video slide sample.



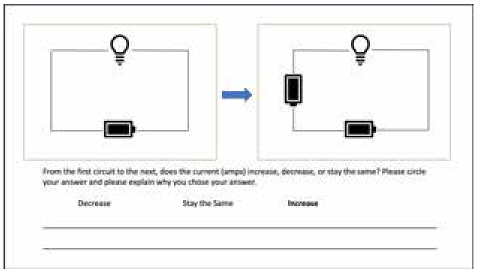
Connecting Batteries in Series – Summary

When you add a battery in series to an existing circuit, the current (amps) is doubled.

Figure 4. Text description slide sample.

Appendix A

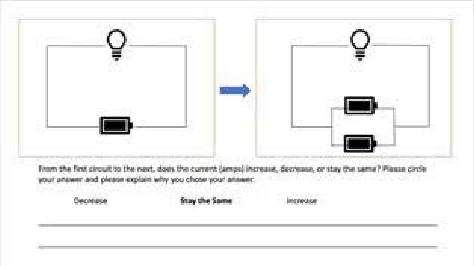
The transfer test questions were displayed as eight separate pages in a packet, displayed in order below.



From the first circuit to the next, does the current (amps) increase, decrease, or stay the same? Please circle your answer and please explain why you chose your answer.

Decrease Stay the Same **Increase**

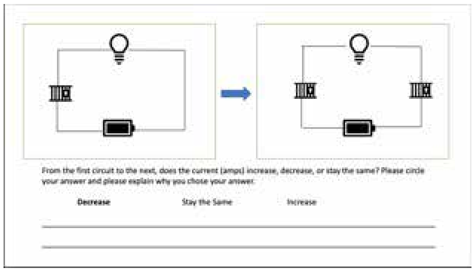
1.



From the first circuit to the next, does the current (amps) increase, decrease, or stay the same? Please circle your answer and please explain why you chose your answer.

Decrease **Stay the Same** Increase

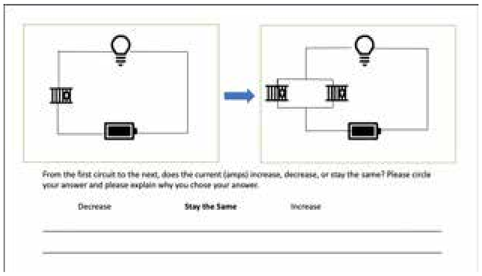
2.



From the first circuit to the next, does the current (amps) increase, decrease, or stay the same? Please circle your answer and please explain why you chose your answer.

Decrease Stay the Same Increase

3.

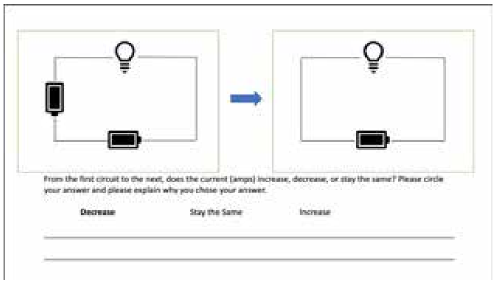


From the first circuit to the next, does the current (amps) increase, decrease, or stay the same? Please circle your answer and please explain why you chose your answer.

Decrease **Stay the Same** Increase

4.

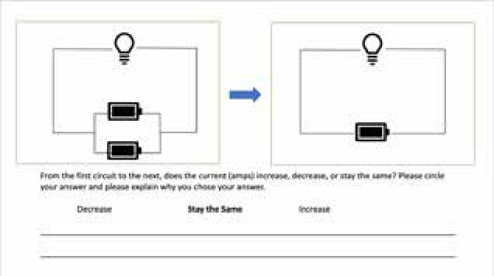
5.



From the first circuit to the next, does the current (amps) increase, decrease, or stay the same? Please circle your answer and please explain why you chose your answer.

Decrease Stay the Same Increase

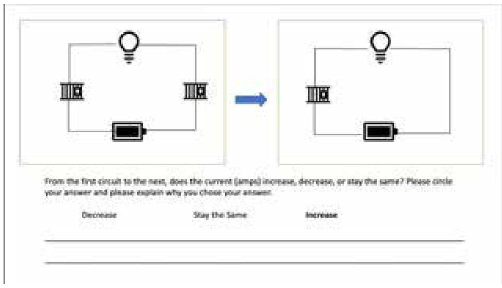
6.



From the first circuit to the next, does the current (amps) increase, decrease, or stay the same? Please circle your answer and please explain why you chose your answer.

Decrease **Stay the Same** Increase

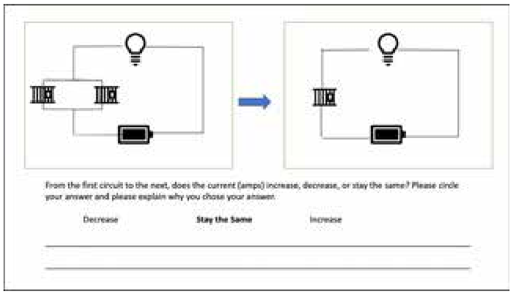
7.



From the first circuit to the next, does the current (amps) increase, decrease, or stay the same? Please circle your answer and please explain why you chose your answer.

Decrease Stay the Same **Increase**

8.

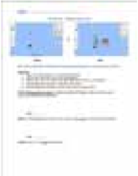


From the first circuit to the next, does the current (amps) increase, decrease, or stay the same? Please circle your answer and please explain why you chose your answer.

Decrease **Stay the Same** Increase

Appendix B

The experimental group worksheet contained five pages with instructions to construct the circuits in order to learn Ohm's law, displayed in order below.



1.

2.

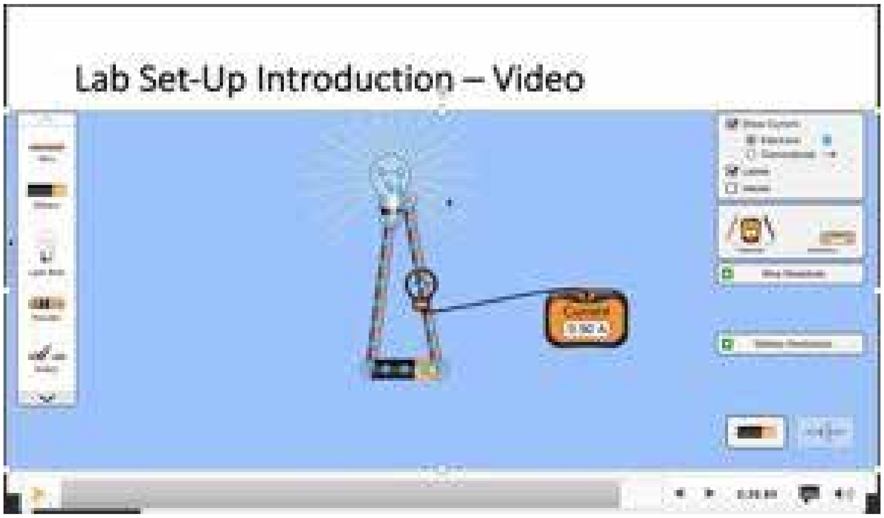
3.

4.

5.

Appendix C

The control group slideshow contained nine slides with a video showing a circuit being constructed followed by a slide explaining the video, in order to teach Ohm's law. The slides are displayed in order below.



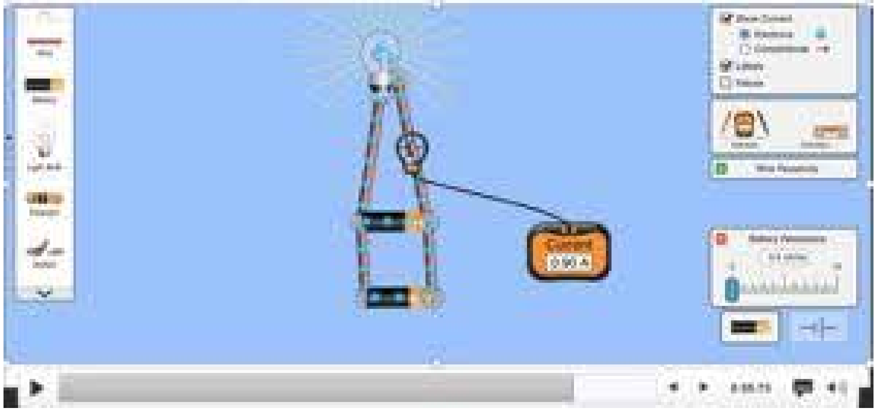
Lab Set-Up Introduction – Video

Connecting Batteries in Series – Video

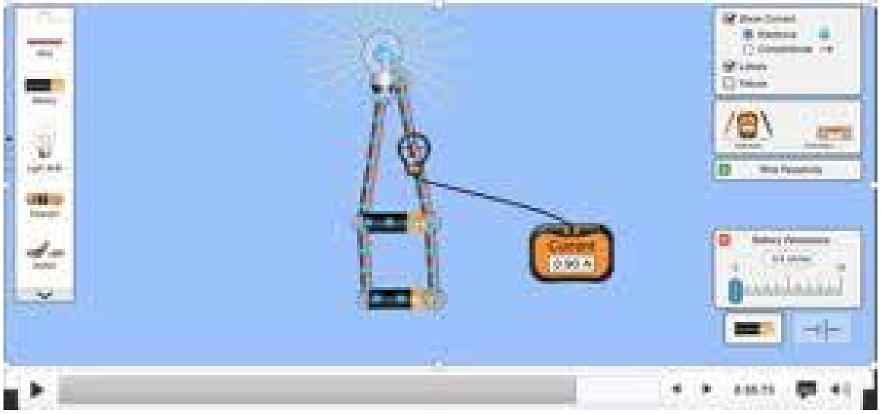
Connecting Batteries in Series – Summary

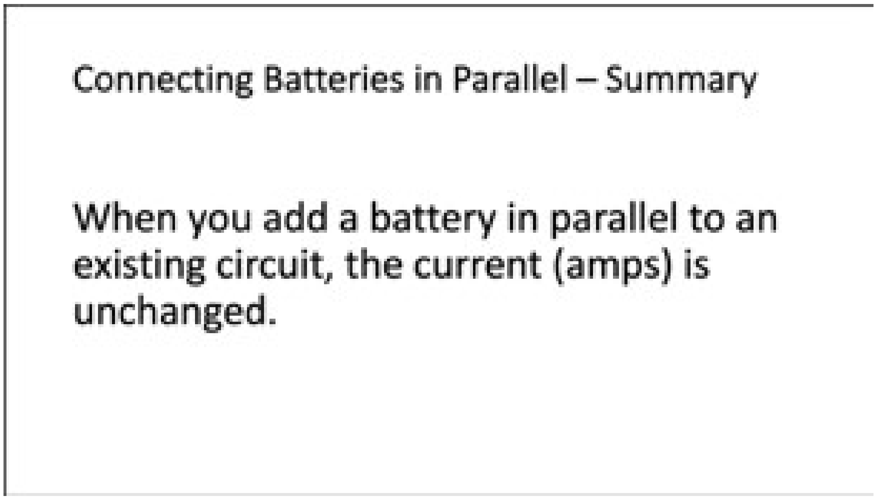
When you add a battery in series to an existing circuit, the current (amps) is doubled.

Connecting Batteries in Parallel – Video



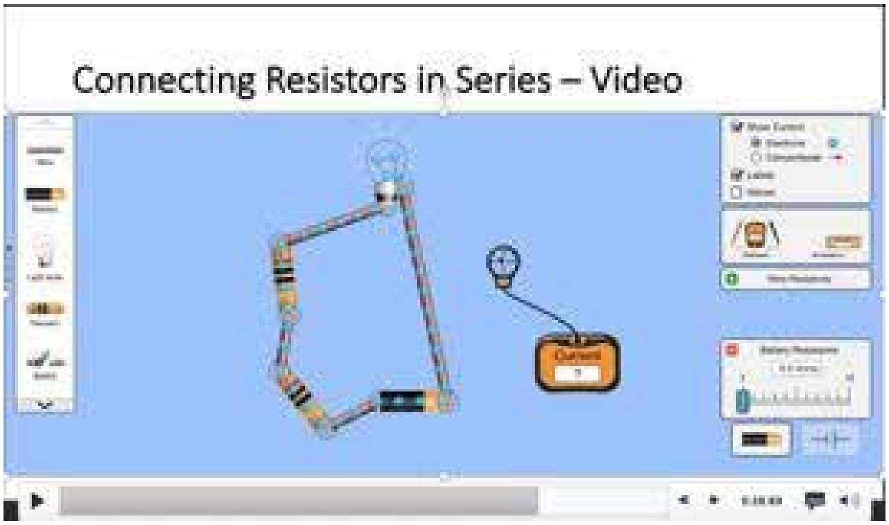
Connecting Batteries in Parallel – Video



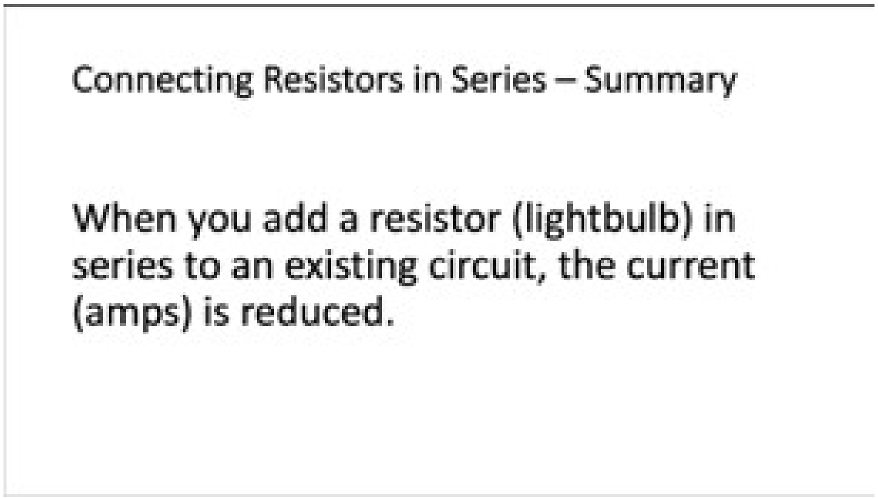


Connecting Batteries in Parallel – Summary

When you add a battery in parallel to an existing circuit, the current (amps) is unchanged.

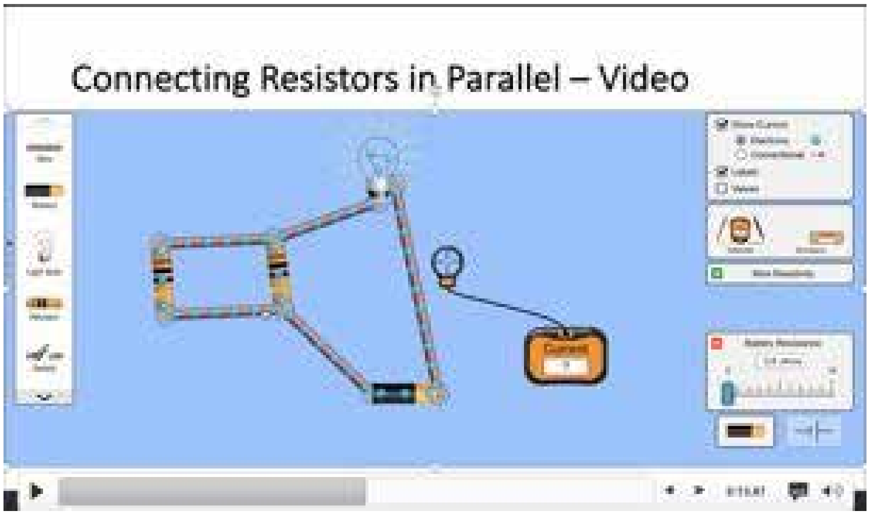


Connecting Resistors in Series – Video

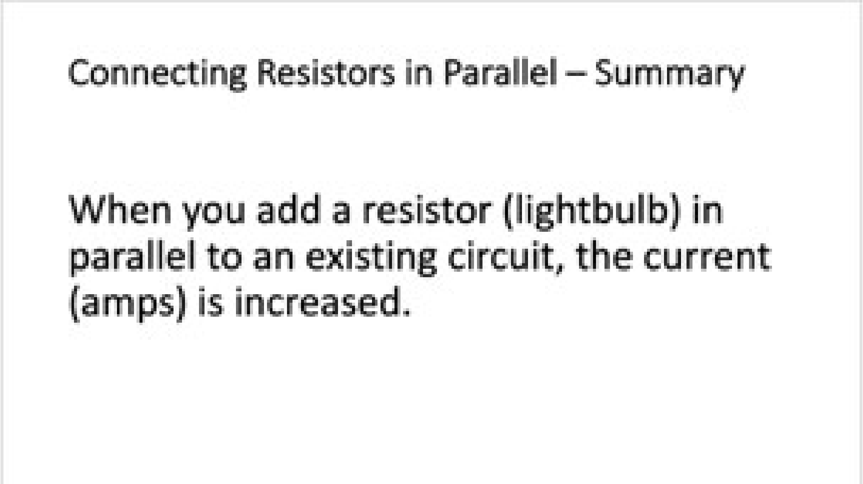


Connecting Resistors in Series – Summary

When you add a resistor (lightbulb) in series to an existing circuit, the current (amps) is reduced.



Connecting Resistors in Parallel – Video



Connecting Resistors in Parallel – Summary

When you add a resistor (lightbulb) in parallel to an existing circuit, the current (amps) is increased.