EPSY 375 Web Project:

Tesla Time: A Web-based Instructional Program Designed to Teach Fifth Grade Concepts of Electricity

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Abstract

The administration of a new science component on the Connecticut Mastery Test has created a difficult situation in that many current fifth graders have not been exposed to third and fourth grade science concepts. This study analyzed the impact of using a web-based instructional program to teach 33 fifth graders fourth grade concepts of electricity. Researchers used both quantitative and qualitative analysis techniques that included matched pair content question analysis as well as a 5-point Likert survey that measured student academic self-efficacy. The program was found to have a statistically significant impact ($p<.001$) on learning about electricity and a significant impact on student academic self-efficacy in studying electricity ($p<.05$). Implications for future use of web-based instructional programs in science are discussed.

Project Summary

Purpose of the Study

The Connecticut Mastery Test (CMT) identifies progress towards the critical goals of reading, writing, and thinking based on the expectations of Connecticut's Common Core of Teaching (CCCT) (Connecticut Mastery Test, 2001). Science is a new component of the test; in 2007 students in grades five and eight will be tested for the first time in this area. The Science CMT will assess students' understanding of the nature of science by embedding questions in a contextual framework. The test places much less emphasis on getting a *right* answer and much more emphasis on the ability to understand how to do performance tasks. For example, a student might be presented with the details of a scientific procedure and asked to modify the procedure to obtain a different outcome. Therefore, questions emphasize students' ability to construct knowledge through active participation in scientific investigations.

Many fifth graders arriving at Mansfield Middle School (MMS) lack exposure to third and fourth grades CCCT science standards (J. Baxter & N. Dickinson, personal communication, September 27, 2006). As one fifth grade teacher stated, "This is probably the first time these kids studied science in school as they don't get a chance to study science in earlier grades." Fifth grade students review the third and fourth grade science curriculum in peer study groups, but there is concern among the faculty that this may not be sufficient preparation for the CMT. To fill this gap, teachers at MMS requested the creation of a web-based instruction (WBI) tool to review the concepts of electricity and circuitry. The resulting project, *Tesla Time*, was named for Nikola Tesla, whose patents and theoretical work relating to modern alternating current electric power systems are numerous.

Setting

Mansfield Middle School is situated in rural Connecticut. Approximately 672 students attend the schools, including 172 fifth grade students. Eighty-five percent of student at the school are White, 8% are Asian, 4% are Hispanic, and 3% are Black. No students at the school receive free or reduced lunch.

Instructional Analysis

Goals and Objectives

After meeting with faculty members, the team decided to design the WBI system to address the fourth grade CCCT Standard 4.4 involving electricity. Specifically, this standard reads, “Electrical and magnetic energy can be transferred and transformed” (Connecticut Department of Education, 2005, p. 16). Performance measurements require that the student be capable of describing how batteries and wires transfer energy to light a light bulb, and how simple circuits can be used to determine which materials conduct electricity.

Team members developed three goals to address Standard 4.4, presented in Table 1. Together, Goals 1.0 and 2.0 scaffold the student toward the ultimate goal of being able to construct a circuit. Goal 1.0 enables the student to understand key concepts such as the nature of electricity as well as the distinctions between conductors and insulators. Goal 2.0 addresses the skill performance requirement within Standard 4.4, and Goal 3.0 focuses on the affective aspects.

In addition to content, the team decided that it was important to measure the affective variable of self-efficacy. Albert Bandura's theory of self-efficacy has been shown in many studies to be a valid predictor of a diverse set of outcomes, such as academic performance, smoking cessation, pain tolerance, career choices, and assertiveness (Schunk, 1991). Self-efficacy has also been shown to sustain motivation and improve skill development , and that it can be a valid predictor of academic performance (Oliver & Shapiro, 1993; Schunk, 1991). The impact of self-efficacy as a performance predictor and a motivator has many implications in education, as well as technology.

Bandura defines self-efficacy as, "…people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives. Self-efficacy beliefs determine how people feel, think, motivate themselves and behave" (Bandura, 1994, p. 1). Examining students' self-efficacy could predict how students might perform in an electrical science test on similar concepts. Multon, Brown, and Lent (1991) stated in their study that, "…self efficacy beliefs account for approximately 14% of the variance in students' academic performance and approximately 12% of the variance in their academic persistence" (p. 34).

The study thus focused on two research questions:

Research Question 1: Will students' academic self-efficacy in studying electricity increase significantly because of the *Tesla Time* program?

Research Question 2: Will students gain significant knowledge involving electricity with the *Tesla Time* program?

Table 1

Goals of the Web Based Instruction Project for Electricity

Goal Number	Description
1.0	The student will understand how circuits use electricity to power devices.
2.0	The student will be able to construct a simulated circuit online.
3.0	The student's self efficacy related to circuits will increase.

In addition to these goals, the team developed a set of measurable objectives that break the goals down further, as shown in Table 2.

Table 2

Objectives of the Web Based Instruction Project for Electricity

Objective Number	Description
1.0	The student will understand how circuits use electricity to power devices. Specifically, the student will understand
1.1	The nature of atoms
1.1.1	Atoms are tiny parts of matter.
1.1.2	Electrons are tiny parts of atoms.
1.1.3	Electrons can break away from atoms and flow.
1.1.4	The flow of electrons makes electricity.
1.2	A circuit is a circular pathway taken by electrons through a material.

- 1.3 Circuits have parts that have different functions.
    - 1.3.1 A power source (e.g.. – battery) supplies electricity.
    - 1.3.2 Electricity flows through a path, usually a wire.
        - 1.3.2.1 Conductors are materials that allow electricity to flow easily.
        - 1.3.2.2 Insulators are materials that do not allow electricity to flow easily.
    - 1.3.3 Electricity can do a job.
        - 1.3.3.1 A load is a device (e.g. a light bulb) that uses electricity to do a job.
        - 1.3.3.2 Energy cannot be created or destroyed, only changed in form.
    - 1.3.4 A switch can interrupt the flow of electricity, turning the flow on or off.
        - 1.3.4.1 Closed circuits allow the movement of electrical energy.
        - 1.3.4.2 Open circuits prevent the movement of electrical energy.

- 2.0 The student will be able to construct a simulated circuit online.
    - 2.1 The student will apply content knowledge by selecting the appropriate part for a particular function.
    - 2.2 The student will apply content knowledge by assembling parts of the circuit in working order.

2.3 The student will use a switch to turn the circuit on or off.

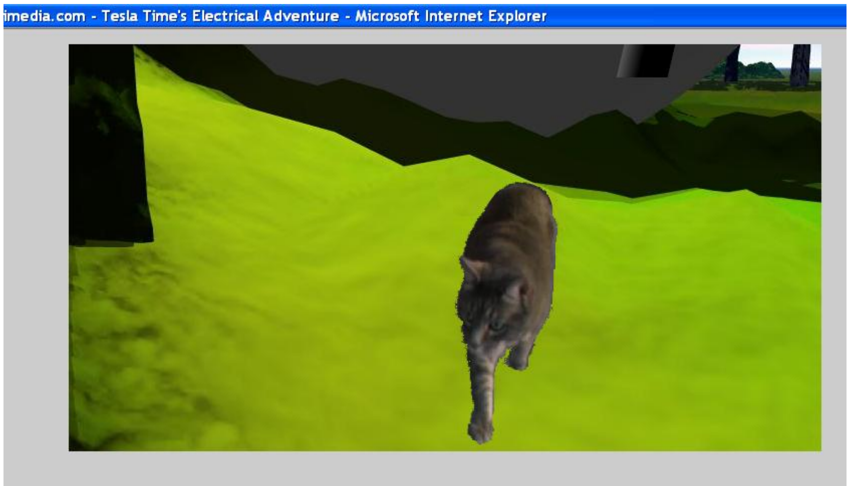
3.0 The student's academic self efficacy related to electricity will increase.

Program Description

The WBI system, *Tesla Time,* presented the learning material in the form of a story centered on a problem. The story cast the student as a character that navigated through a scenario in which he or she encountered a time machine. Entering the time machine, the student came upon a screen that broadcast a message from a future scientist, Caracatus Potts (see Figure 1). Dr. Potts enlisted the student's help in finding his cat, Tesla (see Figure 2), that had wandered into the time machine, transported into the past, and was now lost inside a dark cave. To explore the dark cave and find Tesla, the student had to construct a virtual circuit that would function as a flashlight.

Figure 1. After entering the time machine, the students encounter Caracatus Potts.

Figure 2. Tesla leaves the time machine and enters the cave.

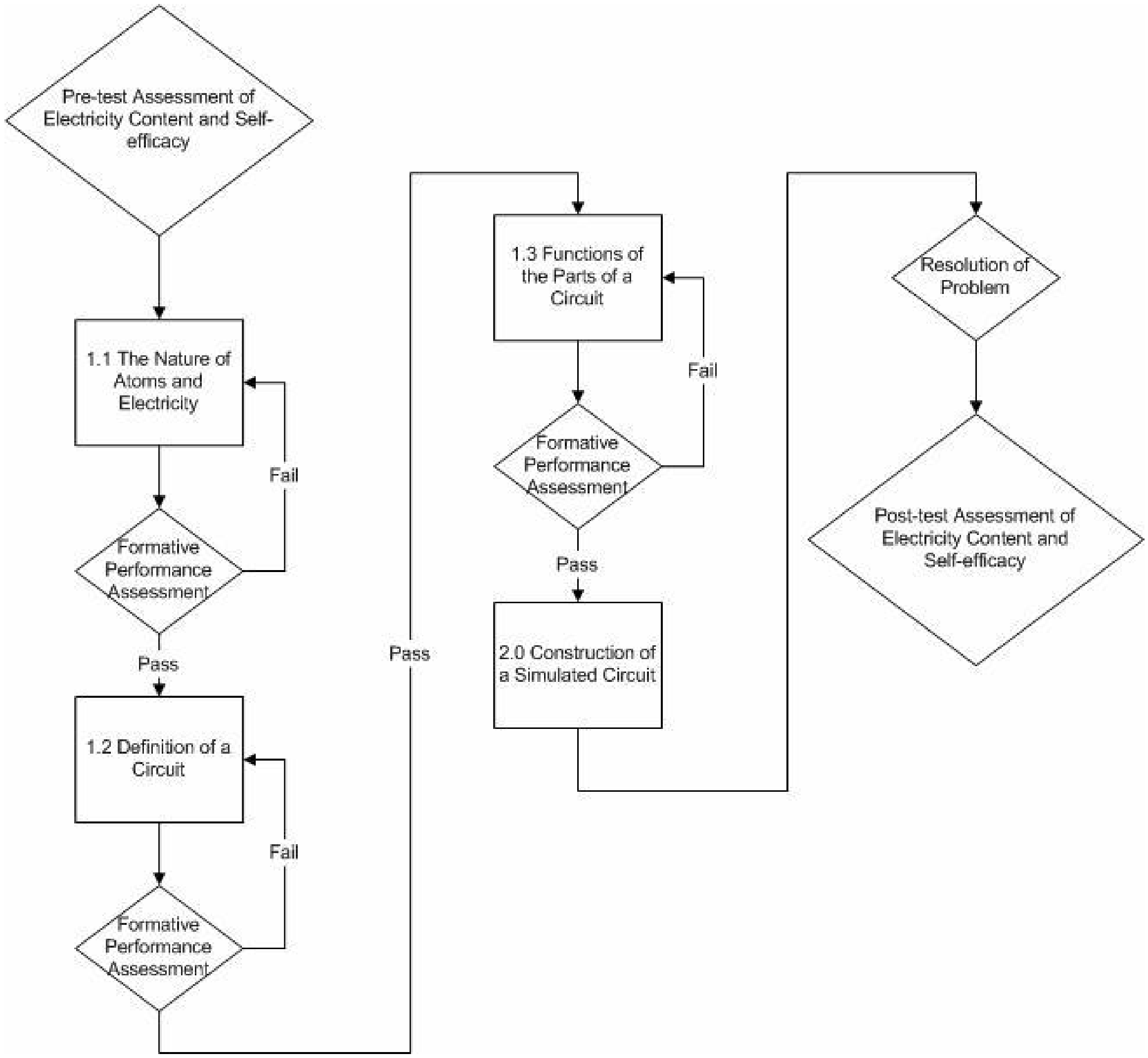


This story-based design offers a number of advantages. *Tesla* Time imbeds learning in context; that is, it enables the learner to construct meaning from his or her experiences and actions. Constructivist learning that requires students to manipulate the environment around him or her to build knowledge has been demonstrated to be an effective pedagogical strategy (Jonassen, 1991). Structuring the scenario as a personalized narrative aids in knowledge transfer by actively engaging the student in the curriculum (Mayer, Fennell, Farmer, & Campbell, 2004).

During the design phase, an attempt was made to make the scenario gender-neutral. Girls often struggle with science throughout adolescence and adulthood, and this struggle often begins in late elementary school (Reis, 1998). An effort was therefore made to incorporate elements that might interest the girls. For example, the story's problem was centered on finding the cat. Several girls stated during the implementation, "I like the cat." The research team tried to find instances of significant contributions in the field of electricity made by women. When none were found, two fictional future scientists were created and incorporated as part of the storyline.

Figure 3 depicts the flow of the WBI. Students began by entering basic registration information, including name, gender, age, school, and grade. Next, they completed a pretest that measured their interest and self-efficacy levels relating to circuits, as well as their content knowledge about the topic. Upon completion of the pretest, the students began the main program, in which they met Caracatus Potts, who framed the problem of constructing the flashlight to find the cat. The student then activated the time machine button, and appeared to travel back in time.

Figure 3. Design flow chart of the web based instruction project for electricity



The remainder of the WBI was divided into segments in which the student encountered various inventors who taught them specific concepts relating to electricity. Specifically, Benjamin Franklin (see Figure 4) instructed the students on the nature of electricity (Objective 1.1) and about batteries (Objective 1.3.1). Caracatus Potts helped the student to understand the nature of circuits (Objective 1.2), wires (Objective 1.3.2), and switches (Objective 1.3.4). Thomas Edison (see Figure 5) taught the student about light bulbs and other circuit loads (Objective 1.3.3). After the completion of these steps, the student constructed the online circuit to light the flashlight, exited the time machine, and found Tesla in the cave. A posttest was then administered that assessed content knowledge and self-efficacy relating to electricity.

Figure 4. Benjamin Franklin describes electricity and batteries with animated instructional elements.

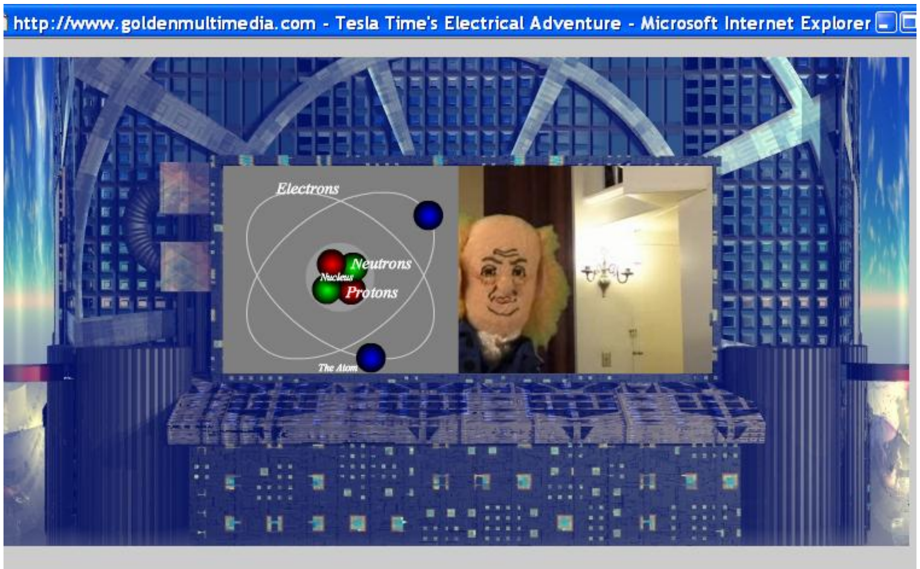
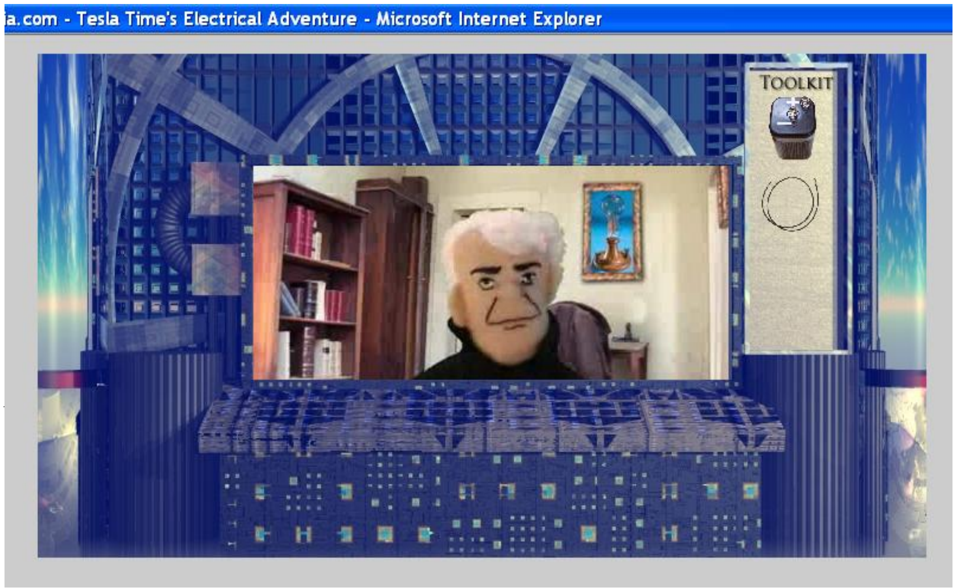


Figure 5. Thomas Edison explains the nature of electrical loads.



The instructional unit was presented via audio, text, graphics, animations, and video embedded in a custom Flash program (Golden, 2006). The interactive Flash program was created in Adobe/Macromedia Flash 8 Professional, and was embedded into an html page for web or local delivery. The varied forms of media in the program were related to each other based on cognitive interest theory. Cognitive interest theory imbeds explanative images with text. (See Figure 4 for an example of how an image of the atom was presented based on cognitive interest theory.) This theory contrasts with emotional interest theory in which seductive images are imbedded that are irrelevant to the material to be learned (Harp and Mayer, 1997). Kintsch (1980, p. 89) summarized cognitive interest theory by stating, “The text as a whole must hang together and make sense to the reader, so that he is able to construct a coherent macrostructure in which each text unit has a place and is meaningfully related to other sections of the text.” Lee, Park, Kim, Son, and Lee (2005) found that students who learned scientific material using PDAs (personal digital assistants) with explanative images significantly outperformed students who learned only using text or text with seductive images. The scientific material in *Tesla Time*, presented as a personalized story with explanative text, images, and video, was thus designed to increase students’ scientific content knowledge and skill performance, as well as students’ electrical science self-efficacy.

For this study, a web based online survey program, Book of Mazarbul (Girasoli, 2006) was created. The Book of Mazarbul program was written in Perl and used a MySQL database back end. The pre- and posttest were administered to students using the Book of Mazarbul program before and after using the *Tesla Time* implementation. When a student took the pre- and posttest, they entered their first and last names, as well as their school, gender, grade, and age. The introductory and final texts, as well as the content questions, were read to the students via an audio file. This added dimension of audio was meant to help students who are challenged with reading comprehension (R. Hannafin, personal communication, October 2006). After the interaction, the Book of Mazarbul program generated reports of raw and performance data for later analysis in SPSS. To match pre- and posttest scores, the Book of Mazarbul attempts to match students' first and last names from the pre- and posttest name data.

Assessment

The WBI system included three types of student assessment: a pretest, ongoing formative assessments, and a summative posttest at the end of the application. Pretest and posttest questions were identical. Each question was designed to measure a specific educational objective related to content knowledge or self-efficacy in the area of electricity.

Content questions (questions 6-17) were administered in either multiple choice or true-false formats. Students read and listened to content questions, as audio accompaniment provided assistance to students who might struggle with reading. Affective questions measuring self-efficacy (questions 1-5) were administered using a 5-point Likert scale with responses ranging from *Not at all* to *Very much*. The self-efficacy questions and scales are based the learning attitudes instrument from the Classroom of the Sea (COS) Project with deaf students (Babb, Brown, & Schifele, 2001). The COS instrument has proven to be reliable and valid in measuring students' attitudes based on Bandura's theory of self-efficacy (Babb, et al., 2001). Input values were captured and stored in a database for later analysis. Table 3 provides a list of questions on the pre- and posttest, and the specific educational objectives with which they are matched. In the case of content questions, the answers are provided in the table in parentheses.

Table 3

Pre- and Posttest Questions and Related Educational Objectives

Question Number	Question	Objectives
1	Do you enjoy studying about electricity?	3.1
2	I understand how electricity is useful in my life.	3.1
3	Do you enjoy studying about science?	3.1
4	I look forward to learning about electricity.	3.1
5	How confident are you (if given the parts) you can build an electrical circuit?	3.2
6	Tiny parts of an atom that orbit the nucleus are called (electrons).	1.1.1, 1.1.2
7	When these tiny parts of atoms break away from the atom and Flow, they produce (electricity).	1.1.3, 1.1.4
8	A circular pathway through which electricity flows is known as a (circuit).	1.2

Table 3 (Continued)

Pre- and Posttest Questions and Related Educational Objectives

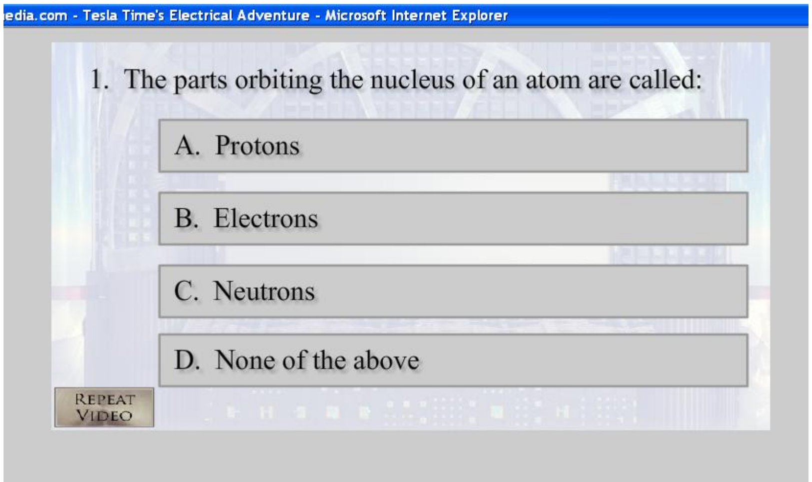
Question Number	Question	Objectives
9	What is the function of a battery in a circuit? (Provide electricity).	1.3.1
10	Electricity needs a path to flow through in a circuit. True or false? (True)	1.3.2
11	Electricity flows easily through materials called (conductors).	1.3.2.1
12	Electricity does NOT flow easily through materials called (insulators).	1.3.2.2
13	A device that uses electricity to do a job is called a (load).	1.3.3.1
14	The Law of Conservation of Energy says that (energy can be changed from one form to another).	1.3.3.2
15	Why does a switch turn off a light bulb in a circuit? (It interrupts the flow of electricity in a circuit).	1.3.4
16	Which type of circuit would allow electricity to flow and light a bulb? (Closed circuit)	1.3.4.1
17	Which type of circuit would NOT allow electricity to flow and would not light the bulb? (Open circuit)	1.3.4.2

After each video segment, students completed similar questions on content as part of ongoing formative assessments (see Figure 6); however, these values were not captured. Rather, the formative assessments were designed be a teaching device that helped students to clarify concepts. During the formative assessment, students were provided with clues if they selected a wrong answer. For example, Question 1 asked “The parts orbiting the nucleus of an atom are called:” If a student selected the wrong answer “neutrons”, the system would prompt, “No, neutrons are part of the nucleus, or center of the atom. They don’t go around it.” A *back* button allowed the student to go back and try the question again. Once the student answered the formative questions for the segment correctly, he or she received the item required for the circuit in his or her online toolkit, displayed on the right side of the screen.

The next segment required students to construct a simulated circuit online. Once a student had collected all of the items necessary to construct the circuit, he or she returned to Caracatus Potts, who explained how the parts work together and challenged the student to construct an online circuit. The student next viewed a description of the function for the part required, and selected the appropriate item from his or her toolkit (see Figures 7 and 8). When the correct part was selected by the student, the program placed the part into the circuit and proceeded to the next part needed.

When the virtual circuit was complete, the students could click the toggle switch to turn the lamp on and off, and then proceed into the cave to find Tesla. Upon return to the time machine, Caractus Potts thanked the students and instructed them in how to send Tesla and the machine back to the future, thus ending the program. At the conclusion of the application, students took a posttest with the same questions as in the pretest. Input values were captured and stored in a database for comparison with pretest values and statistical analysis.

Figure 6. Sample formative assessment question



1. The parts orbiting the nucleus of an atom are called:

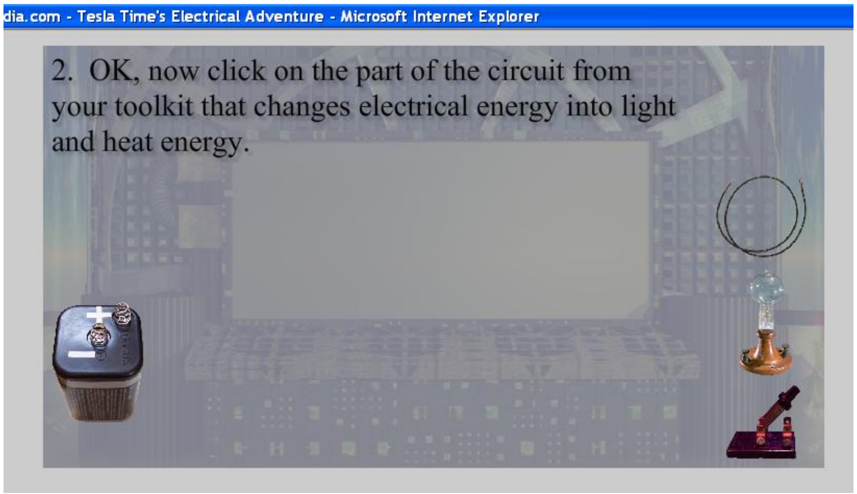
A. Protons

B. Electrons

C. Neutrons

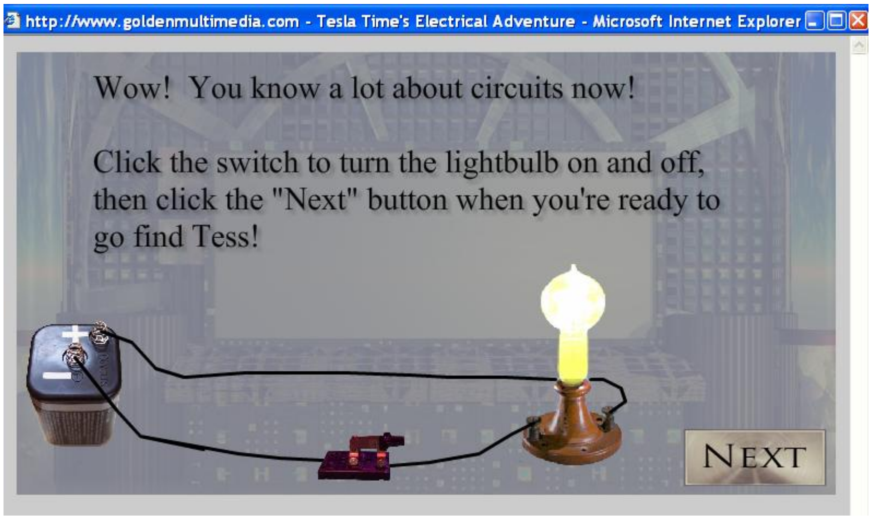
D. None of the above

Figure 7. The student begins to construct the circuit.



2. OK, now click on the part of the circuit from your toolkit that changes electrical energy into light and heat energy.

Figure 8. The student constructs an online circuit to light a bulb.



Wow! You know a lot about circuits now!

Click the switch to turn the lightbulb on and off, then click the "Next" button when you're ready to go find Tess!

Implementation

The research team arrived early at the school to set up in the lab. Because the project relied heavily on video, the team felt it best to preload the application on all computers. It soon became evident that with multiple computers the video would load too slowly, so the application was installed on the school's network server, thereby increasing delivery speed (as compared to web-based delivery)..

Implementation occurred in two separate computer labs over a period of approximately two hours. Each lab contained 23 personal computers running Microsoft Windows. Students remained in the lab for 50 minutes each period. Two classes came at a time, and there were two periods for a total of four classes that received treatment. Approximately 90 students participated. There were eight special education students in the second group. Two of the special education students were in self-contained classrooms for the majority of the day, and were accompanied to the computer lab by two adult aides.

Figure 9 – Many students appeared interested in and engaged by the WBI System.

Most students appeared to remain on-task for the majority of the implementation time (see Figure 9). However, because the first period began late, many students did not have time to complete the activity, to the disappointment of several of them. Two girls were disappointed that they had to stop and remarked, "...but I just got the switch!" Because the majority of students did not have time to take the posttest, data analysis came from the second period group.

Methods and Results

To analyze the data from Mansfield Middle School, a mixed-mode model of quantitative and qualitative methods was used The quantitative data consisted of five Likert scaled questions on interest and self-efficacy in science and electricity, as well as 12 multiple choice content related questions. These data were derived from the pretests and posttest administered immediately before and following the implementation.

Both boys and girls participated in the online assessments, which used the Book of Mazarbul instrument program (Girasoli, 2006) to report raw data and calculate correct scores for the pre- and posttests. Participants were given an identification number for anonymity. If students pressed the *back* button on their browsers to reenter an answer on the online instrument, the most recent answer was used as the final answer. Students who could not be identified as having taken both a pre- and posttest were filtered out of the data. Because first period students weren't able to take the posttest due to time constraints, the sample size was reduced from approximately 90 students to 33. Approximately 40% of the sample was female and 60% were males.

These data were imported for analysis into SPSS, a statistical analysis program. To check for invalid entries that were not within each variable's bounds, a frequency distribution was run on the pre- and posttest surveys. There were no data out of bounds.

Examination of Data for Outliers

Data were analyzed to identify outliers, defined as having *z*-scores +/- 3 standard deviations from the mean (Tabachnick & Fidell, 2001). The percent correct scores contained one outlier, which represented 1% of the total sample data for this group. The individual content answers contained nine outliers, which represented 2% of the total sample data from this group. Self-efficacy scores contained two outliers, representing 1% of the total sample data for the self-efficacy group of questions. Since these outliers represented less than 5% of the data for their respective groups, they were substituted with their corresponding group (pre- or posttest) mean values (Tabachnick & Fidell, 2001).

Analysis of Affective Questions

Reliability of Likert-scaled questions

To examine reliability in the affective data (questions 1-5), a Cronbach's Alpha was processed on the self-efficacy pretest questions, then on the self-efficacy posttest questions. For the pretest questions, the initial reliability was .694. When question 2 was removed, the pretest reliability increased to an alpha of .748. With the posttest questions, the initial reliability was .732. With the removal of question 2, the post-test reliability increased to an alpha of .790. These are the maximum total reliabilities that could be achieved in both pre- and post-test with the removal of items. Question 2 was omitted from the factor analysis.

Data reduction of Likert-scaled questions

A factor analysis was only performed for self-efficacy (questions 1-5). The extraction method was a principal component analysis (PCA). However, due to the small sample size, it is difficult to yield a robust factor solution. Two factors were identified: Factor 1 measured the students' interest and pleasure in learning about electricity, as well as their confidence in their abilities in the topic, and Factor 2 measured students' general enjoyment of science. A varimax rotation was utilized when analyzing the factors. In the factor table, absolute values less than .40 were suppressed. Two factors were forced as computing factors with Eigenvalues greater than 1 yielded only one factor.

For this study, Factor 1 (F1) and Factor 2 (F2) were computed on all subjects by determining the average score across loaded items. The total variance explained by the factor analysis is 79%.

Self-efficacy Items ANOVA

To analyze the self-efficacy factors, a 2 x 2 (Gender x Testing) ANOVA was computed. This ANOVA addressed Research Question 1, "Will students' academic self-efficacy in studying electricity increase because of the Tesla Time program? Factor 1 and Factor 2 were the dependent variables. Gender and Testing were the independent variables. There was a statistically significant interaction between pre- and post-test groups ($F = 3.645, df = 2, 61, p = .032$) at the .05 level. Factor 1 contributed to the significance ($F = 6.570, df = 1, p = .013$) while Factor 2 did not ($F = 0, df = 1, p = .991$). There was also not a statistically significant interaction between the gender groups and testing groups ($F = .384, df = 2, 61, p = .683$) at the .05 level. See Appendix A, Table A for the ANOVA tables regarding self-efficacy scores.

Analysis of Content Questions

To address Research Question 2, a paired-samples *t* test was computed on content questions (6-17) analyzing the percent correct scores of the 33 participants. Research Question 2 presented, "Will students gain sufficient knowledge to satisfy the fourth grade CCCT Standard 4.4 involving electricity with the Tesla Time program?" . There was a statistically significant difference between the means of the pretest (M = 58.2, SD = 13.95) and posttest (M = 80.91, SD = 16.46) scores $t(32) = -9.47, p < .001$ (two-tailed), $d = -1.49$ (see Figure 10). An independent samples t-test was computed to compare the means of the pretest scores and the posttests scores when grouped by gender. There was no statistical significant difference between the means on the pretest *t(*31*)* = .308*, p* = .76 (two-tailed), *d* = .11 and post-test *t(*31*)* = .968*, p* = .341 (two-tailed), *d* = .36.

The data was recoded to categorize each answer as right, with an assigned value of 1, or wrong, with an assigned value of 0. Because the data was paired and categorical for each question, a specific analysis was conducted on questions 6-17. A dependent sample McNemar's test revealed significant differences for questions 6, 7, 9, 12, 13, 16 and 17. (see Table 4). For a breakdown by percentages of both correct and incorrect responses, see Table B in Appendix A.

Figure 10

Mean score comparisons between overall, female, and male groups, pre- and posttest

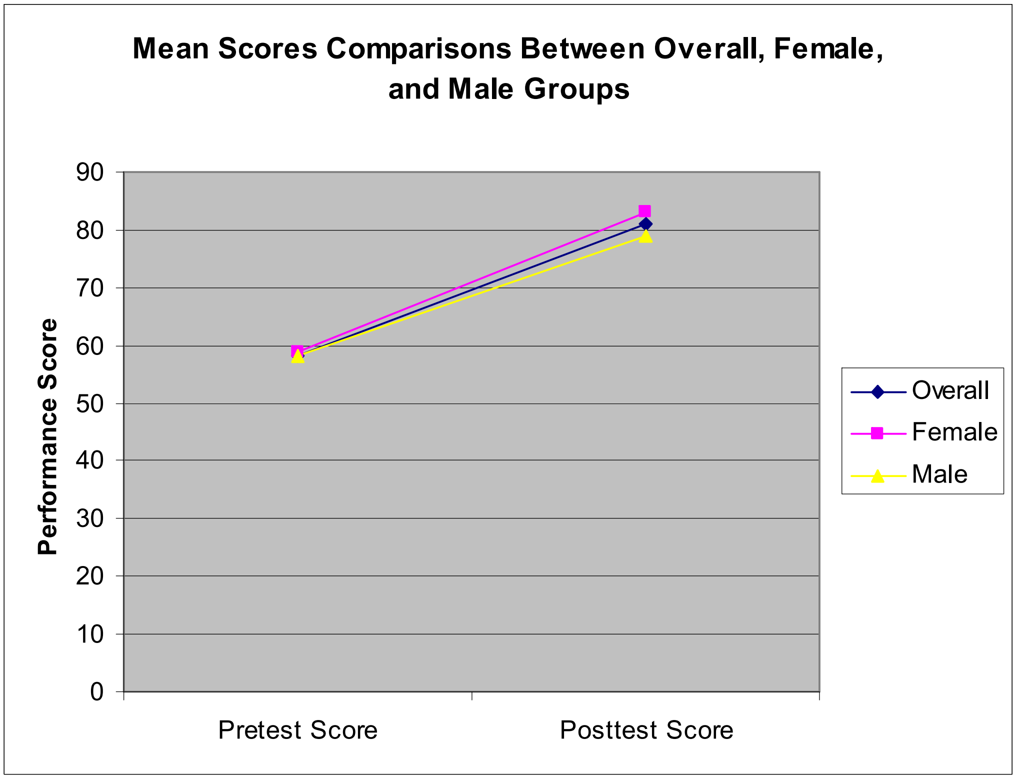


Table 4

Paired Samples McNemar test on content pre- and posttest question pairs, items 6 - 17

Question	Objective(s) And Concepts Measured	Question	% Students Correct on Pretest	% Students Correct on Posttest	Sig. (2-tailed)
Pair 1, Question 6	1.1.1, 1.1.2 – Parts of an atom	Tiny parts of an atom that orbit the nucleus are called…	46%	73%	.035*
Pair 2, Question 7	1.1.3, 1.1.4 – Flowing electrons make electricity	When these tiny parts of atoms break away and flow, they produce…	55%	76%	.039*
Pair 3, Question 8	1.2 – What a circuit is	A circular pathway through which electricity flows is known as a…	97%	88%	.625
Pair 4, Question 9	1.3.1 – The function of a battery	What is the function of a battery in a circuit?	46%	76%	.006*
Pair 5, Question 10	1.3.2 – The function of a wire as a path through which electricity flows in a circuit	Electricity needs a path to flow through in a circuit.	100%	94%	.50
Pair 6, Question 11	1.3.2 – What a conductor is	Electricity flows easily through materials called…	85%	91%	.68
Pair 7, Question 12	1.3.3 – What an insulator is	Electricity does NOT flow easily through materials called…	67%	88%	.039*
Pair 8, Question 13	1.3.3 – The function of a load	A device that uses electricity to do a job is called a …	15%	55%	.001*

Table 4 (Continued)

Paired Samples McNemar test on content pre- and posttest question pairs, items 6 - 17

Question	Objective(s) And Concepts Measured	Question	% Students Correct on Pretest	% Students Correct on Posttest	Sig. (2-tailed)
Pair 9, Question 14	1.3.3 – Energy can be changed in form.	The Law of Conservation of Energy says that…	21%	72%	<.001*
Pair 10, Question 15	1.3.4 – The function of a switch	Why does a switch turn off a light bulb in a circuit?	73%	70%	1.000
Pair 11, Question 16	1.3.4.1 – What a closed circuit does	Which type of circuit would allow electricity to flow and light a bulb?	39%	82%	.003*
Pair 12, Question 17	1.3.4.2 – What an open circuit does	Which type of circuit would allow NOT electricity to flow and would not light the bulb?	61%	85%	<.001*

Qualitative Observations

Bandura stated that “Students' belief in their capabilities to master academic activities affects their aspirations, their level of interest in academic activities, and their academic accomplishments” (Bandura, 1994, p. 1). Renzulli (1977) emphasized the importance of student interest and engagement, and pleasure on learning gains. Because interest and pleasure in learning are related to self-efficacy and learning gains, the research team decided to structure their qualitative observations and questions around these variables.

Pleasure and enjoyment

The majority of students appeared to enjoy the activity. A variety of students' comments were noted. Several students noted that approval by stating, "Cool!" Another was heard to comment, "Oh, yeah! 1925!" Another student turned to the person next to her and said, "That's funny. Did you get to the part when he says, 'She's afraid of the dark?'" Still another student was laughing at the Benjamin Franklin finger puppet – hitting his fist on the desk lightly as he was laughing. One child appeared engaged as he was making time travel noises when the time machine went into the past.

Several students were randomly selected for an exit interview and were asked the following questions:

Did you like or dislike the computer activity you just did?

What did you like about it?

What did you dislike about it?

What would you change about it?

Out of 17 students interviewed, 15 students liked the WBI and made positive comments such as:

I really liked it. It was fun.

It was fun and interesting.

I liked it. I wouldn't change anything.

I liked that it tells you how electricity works.

I liked the cat.

I liked the time machine…a lot.

One student expressed dissatisfaction with how long the videos were: “I think the videos should be much shorter. Another student said that finger puppets should not be used “for older kids” and the whole thing should be “made virtual”.

Interest and engagement

Observations on student engagement were mixed. Most of the students appeared to be engaged for a majority of the time. However, some students were observed to be glancing around at others while the videos were playing. One student tried to grab another student’s mouse, causing the second one to guard his mouse. Side conversations took place during some videos. Classes were noisier and more off-task at the beginning of the periods, and then settled down as the period progressed and they became more engaged with the program.

Several students appeared to be concerned with the length of the videos. One student placed his hand over the image of Potts’ and noted, “He’s talking again!” Another student complained, “It’s like an hour long!” A third student asked, “Why do they have to talk so much?”

Conclusions

Technical Considerations

Overall, Tesla Time’s strong multimedia component that integrated video, audio and graphics proved to be a strong feature of the WBI. Many students were motivated and highly engaged. Students’ comments showed that they appreciated the high quality video and audio of the learning segments.

The major technical issue relating to the web-based delivery arose from the fact that the program was video-based. Because streaming video was used, when 10 or more computers were downloading from the website, the video would begin to falter. This issue was overcome by having the students run the program off of a local network server as opposed to streaming the video over the internet. Another possible fix to this problem would be to have the students run the scenario in small groups in their classroom computers a few at a time, or as a homework assignment. If web-based implementation must be maintained, creating multiple "mirror" websites for streaming is advised.

Running the program locally on the network server did create a problem with students accessing the posttest (a built-in Flash security feature that restricts local files from accessing the internet), so students were instructed to raise their hands when complete, and a teacher or researcher would open the posttest for them. Students running the program from the web would not have this problem.

Another concern was that if students right-clicked the Flash program, an option was available that could send the student back to the beginning. One student did this on one occasion and expressed frustration. Right-clicking was disabled for future use, and an administrator's page was added so that a teacher or researcher could jump to a particular segment of the WBI.

During the implementation, it was noticed that some text was missing from the formative assessments. This may have been due attributes of the text in the program, or it may have been caused by the local network access instead of web implementation. Researchers circulated through the room and verbally prompted students on the missing text. Fortunately, no text was missing from the summative assessments, which was the source for the quantitative data analysis. After implementation, this issue was examined off-site, where it did not occur. The text was adjusted to prevent future problems.

Logistical Considerations

Taking into account several logistical considerations would make implementation smoother and more successful. For example, because there were 23 computers in close proximity to each other in each lab, but only headphones for approximately 80% of students, the rooms became noisy with audio. Some students appeared distracted by the noise, especially during the long videos. It is recommended, then, that each student have his or her own set of headphones.

Although some of the noise in the room was from the program, additional noise came from student conversations taking place during videos. This not only contributed to the noise level, but it also distracted the students while the informational videos were running. Students were also seen to be sharing answers on the pre- and posttest. A possible solution to this problem would be to seat the students boy-girl, or at least not next to the friends with which they socialize.

Another logistical consideration would be to spend more time investigating the school environment and how it is structured. Specifically, length of periods needs to be taken into account, as well as technical requirements of the school's computer lab. Although students could finish in the time allotted for the period, there was no room for delays in getting started, or if large amounts of time were taken on the pre and posttests. The first period group arrived slightly late and had to leave on time. Consequently, they did not finish the entire program and posttest. Similarly, technical requirements of the school's computer lab make quick fixes a necessity, and may have hampered the overall effectiveness of the program for some. A trial run-through on-site prior to the day of implementation would have helped. By investigating these issues early and thoroughly, implementation would be improved.

Instructional Considerations

Students who participated in the *Tesla Time* implementation demonstrated a significant increase in short-term learning gains about electricity and circuits (p=.001). Overall, the program was extremely effective. However, students' scores reflected higher achievement of some objectives than with others.

Content question analysis

Significant gains were demonstrated on 10 content objectives; one objectives showed gain, but not significant; three objectives showed insignificant loss.

Objectives that concerned the nature of electricity (1.1.1, 1.1.2, 1.1.3, 1.1.4) showed significant gains between pre- and posttest measures (p=.035 and p=.039) This was the segment taught using the Benjamin Franklin puppet. Interest appeared high during this first time travel segment and so that may account for part of the results. Another consideration is that relatively few (46%) students understood the nature of electricity before, so there was much room for improvement.

A particularly significant gain (p=.006) was demonstrated on Objective 1.3.1 that concerned the function of the battery. Student responses on the pretest indicate that 42% of students selected the incorrect response that a battery's function was to "let the electricity flow through it." No students selected that response on the posttest, indicating that many had changed their answers to the correct response of "provide electricity." Consistent with cognitive interest theory that states that graphics that are meaningful and related to learning improve learning (Harp and Mayer,1997) this segment of instruction was accompanied by animated diagrams of a battery showing the terminals and motion of electrons in an atom (see Figure 8).

It is interesting to note the differences between a pair of related objectives: 1.3.2.1 asks the student to identify a conductor by definition, as opposed to 1.3.2.2 that asks a student to identify an insulator by definition. Many students already knew what a conductor was (85% on the pretest), but only 67% knew what an insulator was. Consequently, greater significance was obtained on the question regarding the insulator (p=.039) than on the question regarding the conductor (p=.68), even though percentage of students selecting the correct answer on the posttest was comparable on the two questions (91% on the conductor question and 88% on the insulator question). It is possible that, prior to instruction, students were able to relate the word *conduct* to *conductor* and determine the meaning from inference, a task which would be harder with the word *insulate.*

Very significant results (p=.001) were obtained on Objective 1.3.3.1 that asks students what an electrical load is. Only 15% of students understood the meaning of the term on the pretest, while 55% demonstrated this knowledge on the posttest. Forty-six percent of students on the pretest indicated that they thought a battery “uses electricity to do a job”; the correct response is a load. This particular segment utilized the Thomas Edison puppet, who defined the concept using the exact words in the question, “A load is a device that uses electricity to do a job.” Repeated several times, and accompanied again by explanatory graphics, this definition may have helped to solidify the concept in students’ minds.

Another strong result (*p*<.001) was the increase in students' understanding of the Law of Conservation of Energy that states that energy cannot be created or destroyed, only changed from one form to another. Measured by Objective 1.3.3.2, the percentage of students selecting the correct answer improved from 21% on the pretest to 72% on the posttest. This concept was actually introduced in one segment and reinforced in two others, once again emphasizing the importance of repetition of a concept. A total of three graphics were dedicated to the idea, with two of the graphics visually displaying the name of the theory on the screen, which may have served to visually reinforce the concept

The related concepts of closed and open circuits (Objectives 1.3.4.1 and 1.3.4.2) both showed significant learning gains (*p*=.003 ;*p*<.001, respectively). These concepts were taught by Caracatus Potts, who had an actual assembled circuit in front of him. He led the students, step by step, along the path of electricity flowing through the circuit, reinforcing previously taught concepts such as insulators and conductors. He demonstrated closed and open circuits a number of times by placing first a switch, and then a variety of insulators (e.g. rubber and a frisbee) and conductors (e.g. a metal pipe and metal fork) in the place of the switch. Each time he would use the specific electrical vocabulary terms *open circuit* and *closed circuit* The repetition and reinforcement of specific vocabulary may have aided in concept retention.

Three objectives actually showed decreases between the pre- and posttest, although they were statistically insignificant. Two cases were comparable in that they started with very high pretest scores and so a ceiling effect may have been responsible. Student scores declined on both the concepts of what a circuit is (p=.625) and the function of a wire as a path through which electricity flows (p=.50). However, pretest scores on these objectives were 97% for the concept of a circuit and 100% for the function of the wire. One or two students changing their answer can thus greatly affect these outcomes. The third case in which scores declined concerned the function of a switch in a circuit (Objective 1.3.4). Scores declined from 73% on the pretest to 70% on the posttest (p<1.0). It is interesting to note that this concept was taught in the same segment as the concepts of closed and open circuits, and that learning gains for those two concepts increased significantly. Two factors may be responsible. First, no diagram or image accompanied the video on the concept of a switch, and much more time was devoted to the concept of types of circuits than to the concept of a circuit switch. Thus, significant explanation and reinforcement may have been responsible for the lack of progress in this learning objective.

Skill performance analysis

Since all students successfully completed the construction of an online circuit, the success rate on Objective 2.0 was 100%. However, due to time restrictions, the task was not as complex as initially envisioned. To truly measure the objective, the student should have to select the appropriate part, and then place it in the correct sequence to construct the circuit. The placement of circuit parts in this task (Objective 2.2) was facilitated by the computer. Given more development time, this feature could be made to be more dependent on the students' placement of circuit parts in two or three dimensional space.

Affective performance analysis

In the self-efficacy analysis, there was a statistically significant interaction between pre- and post-test groups (*F = 3.645, df = 2, 61, p = .032*) at the .05 level. This finding suggests that students' academic self-efficacy towards electricity could have been raised by the Tesla Time program. The ANOVA that analyzed the self-efficacy questions was comprised of two factors. Factor 1 contributed to the significant finding (*F = 6.570, df = 1, p = .013*) while Factor 2 did not (*F = 0, df = 1, p = .991*). Factor 1 measured confidence and enjoyment in studying electricity. Factor 2 measured enjoyment in studying general science. Self-efficacy is task specific (Bandura, 1994) and this aspect may describe the difference in significance between the two factors. Factor 1 was a better measure of students' academic self-efficacy in studying electricity but Factor 2 was not.

Confidence is related to one of Bandura's four sources of self-efficacy, mastery experiences. Mastery experiences are the most effective way of creating a strong sense of efficacy. A mastery experience is when a person is convinced they have what it takes to succeed. This is important; when a person knows they can succeed at a certain task, they will persevere in the face of adversity and quickly rebound from setbacks (Bandura, 1994). Having this belief strongly motivates a person to overcome obstacles and become more proficient in a task.

Enjoyment is an aspect of Bandura's fourth source of self-efficacy, somatic and emotional states. If someone has reduced stress, or is in a good mood, they will have increased self-efficacy related to the task at hand. Factor 1 combines both of these sources of self-efficacy. It appears that these two sources were changed by the *Tesla Time* interaction. How these sources were affected requires more research. As the technology aspect (the *Tesla Time* program) wasn't controlled in this study, it would be beneficial to determine if the technology or teaching method was responsible for the change in academic self-efficacy.

If students' academic self-efficacy increased, it's possible their academic performance in studying electricity will increase as well. Schunk (1991) has stated that many studies have examined self-efficacy as a predictor of academic performance. There have been significant and positive correlations between self-efficacy and the prediction of motivation and achievement. Self-efficacy has also shown to be a predictor of exam performance (Vrugt, Langereis, & Hoogstraten, 1997). If the *Tesla Time* interaction increased students' academic self-efficacy of electricity, it's possible these students will be motivated to learn more and perform better when studying electricity.

Other considerations

Several students appeared to be confused about the historical anachronisms and the inclusion of future inventors. As Benjamin Franklin discussed electricity, one student was overheard saying, "How does he know what a battery is?" Another student asked of one of the researchers whether or not the female scientist of the future would really invent the time machine. It was anticipated that there might be some confusion relating to the real and imaginary, so the script included references to how parts of the scenario were not real. Many students appeared clear on the fact; however, several did not.

Table 5

Considerations for Future Implementation

Area of Consideration	Description of Concern or Strength	Recommendations for Future Implementation
Technical	Streaming video slow or halted.	Run computers in smaller groups, from home, or local server. If web-based implementation is needed, create mirror websites. Have a trial-run at the school site prior to implementation.
Technical	Students could “rewind” to the beginning of the implementation if they right-clicked.	Disable right-clicking and install an administrator’s page that would enable a teacher to bring a student back to his or her location in the WBI.
Technical	Links from locally run Flash programs may not allow access to online content	Access can be allowed from each computer (Administrator rights needed), or web-based delivery can be used (which avoids the problem).
Logistical	Noise level in the room was high at times.	Give each student a set of headphones. Seat students apart from their friends.
Logistical	Many students did not finish the program.	Streamline what is taught to shorten implementation. Begin each period on time.
Content	Students scored higher on objectives that utilized explanatory graphics and text to reinforce ideas.	Add more explanatory text and graphics in the form of captions and diagrams to accompany script.
Content	Students scored higher on objectives that used the exact terminology in the script as in the pre- and posttest.	Agree upon specific wording for content vocabulary. Check script to ensure fidelity with wording.
Content	Students scored higher on objectives that were taught using multiple modalities of learning (e.g. visual and audio).	Look for ways to incorporate other modalities of learning in the implementation.

Table 5 (continued)

Considerations for Future Implementation

Area of Consideration	Description of Concern or Strength	Recommendations for Future Implementation
Content	The program assisted in circuit part placement. (due to developmental time constraints).	Redesign the segment such that the students are more responsible for correctly placing parts in circuit.
Affective	It was not clear as to what (teaching method or technology) was affecting the students' sources of self-efficacy.	Control for technology in future studies by having experimental and control groups.
Other	Some students appeared confused as to the imaginary vs. the real in the program.	Rework the scripts to make these clearer.

Limitations of the Study

This study provided valuable information concerning the implementation of a web-based instructional unit at the fifth grade level. However, findings from this investigation need to be viewed in the light of several limitations. First, the sample size was fairly small (*n*=33). Because students ran out of time and were not able to take the posttest, a larger sample could not be obtained. A second problem is that the WBI was only tested at one school. Thus, external validity may be a concern. A final limitation of the study involves students' sharing of answers on the pre- and posttest. Because this activity was not expressly forbidden, students felt free to share information. It is difficult, therefore, to obtain a true picture of one student's knowledge prior to and after implementation, a factor that may compromise reliability.

Future Research

It is interesting to note that during the implementation of *Tesla Time* both affective and instructional gains occurred. That is, students' self-efficacy relating to the concepts of electricity and circuits appeared to increase as well as their content knowledge of the topics. Further research is needed to determine the interaction of these two areas in web-based learning. Do Bandura's theories of self-efficacy apply as strongly to web-based learning as they do to the traditional classroom environment? More specifically, did the delivery of instruction through web-based technology contribute to the increase in students' self-efficacy?

Another area for research might be to explore using technology to decrease the gender gap in science. Although *Tesla Time* showed no significant differences between girls' and boys' self-efficacy or achievement levels, early middle school is only when that gap is starting to appear (Reis, 1998). Would the incorporation of concepts traditionally ascribed to girls' interests (e.g. the cat) through the mode of technology have an impact on their achievement levels in science? Web-based instructional programs such as *Tesla Time* could be created to specifically examine factors such as this.

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Appendix A

Data

Table A

ANOVA Tables for Gender x Testing Groups for Self-Efficacy Scores

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Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.985	2045.589(a)	2.000	61.000	.000
	Wilks' Lambda	.015	2045.589(a)	2.000	61.000	.000
	Hotelling's Trace	67.069	2045.589(a)	2.000	61.000	.000
	Roy's Largest Root	67.069	2045.589(a)	2.000	61.000	.000
Gender	Pillai's Trace	.029	.908(a)	2.000	61.000	.409
	Wilks' Lambda	.971	.908(a)	2.000	61.000	.409
	Hotelling's Trace	.030	.908(a)	2.000	61.000	.409
	Roy's Largest Root	.030	.908(a)	2.000	61.000	.409
Testing	Pillai's Trace	.107	3.645(a)	2.000	61.000	.032
	Wilks' Lambda	.893	3.645(a)	2.000	61.000	.032
	Hotelling's Trace	.120	3.645(a)	2.000	61.000	.032
	Roy's Largest Root	.120	3.645(a)	2.000	61.000	.032
Gender * Testing	Pillai's Trace	.012	.384(a)	2.000	61.000	.683
	Wilks' Lambda	.988	.384(a)	2.000	61.000	.683
	Hotelling's Trace	.013	.384(a)	2.000	61.000	.683
	Roy's Largest Root	.013	.384(a)	2.000	61.000	.683

a Exact statistic
b Design: Intercept+Gender+Testing+Gender * Testing

Appendix A

Data

Table A

ANOVA Tables for Gender x Testing Groups for Self-Efficacy Scores

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Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Factor1	3.738(a)	3	1.246	2.920	.041
	Factor2	.596(b)	3	.199	.398	.755
Intercept	Factor1	1207.500	1	1207.500	2829.658	.000
	Factor2	1353.308	1	1353.308	2712.336	.000
Gender	Factor1	.766	1	.766	1.796	.185
	Factor2	.217	1	.217	.435	.512
Testing	Factor1	2.803	1	2.803	6.570	.013
	Factor2	5.83E-005	1	5.83E-005	.000	.991
Gender * Testing	Factor1	.002	1	.002	.005	.944
	Factor2	.364	1	.364	.729	.397
Error	Factor1	26.457	62	.427		
	Factor2	30.935	62	.499		
Total	Factor1	1281.111	66			
	Factor2	1441.000	66			
Corrected Total	Factor1	30.195	65			
	Factor2	31.530	65			

a R Squared = .124 (Adjusted R Squared = .081)
b R Squared = .019 (Adjusted R Squared = -.029)

Appendix A

Data

Table B

Content Question Analysis

	Question Number	Pretest	Posttest	Sig. (2-tailed)
Pair 1	6	21% - protons 18% - neutrons *46% - electrons* 15% - molecules	12% - protons 9% - neutrons *73% - electrons* 6% - molecules	.035*
Pair 2	7	33% - friction *55% - electricity* 12% - heat	12% - friction *76% - electricity* 12% - heat	.039*
Pair 3	8	3% - circle *97% - circuit (ceiling effect)*	3% - circle 3% - oval *94% - circuit*	.625
Pair 4	9	*46% - Provide electricity.* 3% - Provide heat. 9% - Make it so device can turn on or off. 42% - Let the electricity flow through it	*76% - Provide electricity.* 6% - Provide heat. 18% - Make it so device can turn on or off.	*.006
Pair 5	10	*100% - True (ceiling effect)*	*94% - True* 6% - False	.50
Pair 6	11	9% - insulators *85% - conductors* 6% - magnets	6% - insulators *91% - conductors* 3% - resistors	.68
Pair 7	12	*67% - insulators* 27% - conductors 6% - magnets	*88% - insulators* 3% - conductors 6% - resistors 3% - magnets	*.039
Pair 8	13	18% - wire 46% - battery 21% - switch *15% - load*	9% - wire 27% - battery 9% - switch *55% - load*	*.001

Table B

Content Question Analysis

	Question Number	Pretest	Posttest	Sig. (2-tailed)
Pair 9	14	15% - Energy can be used up. 58% - More energy can always be created. *21% - Energy can be changed from one form to another.* 6% - Energy can never change.	6% - Energy can be used up. 9% - More energy can always be created. *72% - Energy can be changed from one form to another.* 13% - Energy can never change.	<*.001
Pair 10	15	24% - It disconnects the battery from the circuit 3% - It makes the battery give more electricity *73% - It interrupts the flow of electricity in a circuit*	21% - It disconnects the battery from the circuit 6% - It makes the light bulb burn out 3% - It makes the battery give more electricity *70% - It interrupts the flow of electricity in a circuit*	1.0
Pair 11	16	*39% - Closed circuit* 61% - Open circuit	*82% - Closed circuit* 18% - Open circuit	*.003
Pair 12	17	62.5% - Closed circuit *37.5% - Open circuit*	15% - Closed circuit *85% - Open circuit*	<*.001

Appendix B

Scripts

Scripts for Tesla Time
A Web-Based Instructional Program

Script 1: Introduction

Caracatus Potts: Tess! Tess! Are you there? *(Static on screen)* Oh, where are you Tess!? I can't see you. *(Screen clears, revealing an exaggerated, panicked scientist).* Oh, hello, there. You're not Tess? Have you seen Tesla? He's about this tall and this long *(motions with hands)*. How silly of me! You don't know about Tesla do you? You see, Tesla is my cat, and it seems I've LOST her and I'm SO upset. I turned my back for just one teeny tiny second to make an adjustment to my time machine, and she must have wandered in. The door slammed shut, and the next thing, BAM! WHAM! The time machine just took off into the past!

YOU must be in the past! Here's it's the year 2339 and my name is Caracatus Potts. I've been tinkering with my time machine and I've lost my Tess. What year is it there? What? I can't hear you. There must be something wrong with the audio at my end.

Anyway, please listen. You've got to help me. Won't you please help me find my little feline domesticated mammal friend…er, my cat? She's very special to me. Just look around the time machine and see if you can find her. She's got to be there somewhere and she's very easy to spot. She's grey and (*pauses)*…Uh oh. Do I see an open door? Did the time machine's door come open? Oh, no. This is the worst possible thing that could happen. Tess is very curious, you see, and I'm sure she's wandered outside. You'll just have to go outside to look for her. I see there's a dark cave out there, and Tess would just LOVE to explore that, but don't be afraid, I have a flashlight in the time machine. If you look under the…the… *(pauses)*… Oops! *(Scientist holds up a flashlight).* I forgot! I stepped out of the time machine to GET the flashlight, so…I have it here.

Hmm…this is a pickle because there are no more flashlights on board, and it looks like it's really dark in that cave. You're going to need some light.

Now I'd love to be able to just transport another flashlight back to you, but you have my time machine, you see. And you can't come into the future to meet me. Oh, no, no, that wouldn't do at all. There are definite rules against that sort of thing. So what will we do?

*(Pauses…thinks…scratches his head)*Wait! I've GOT it. You aren't allowed to travel into the future, but there's nothing that says you can't travel into the past! And maybe you don't have a flashlight there, but we've got a way for you to MAKE one! But it involves time travel, which is convenient, because you are, after all, IN a time machine. Are you ready? Can you do it? (*Pauses, strokes chin…)* You LOOK pretty brave. All right, let's give it a try.

Appendix B

Scripts

Now, there are some instructions, so listen carefully. I'm going to have you activate the controls of the machine. Each time you activate the controls, you'll travel into the past to visit some important inventors. You're not allowed to LEAVE the time machine because you might interfere with the past and that would be BAD, very bad. So you're going to remain inside the machine, but communicate with some famous inventors from the past. You see, in order to MAKE the flashlight you'll need to BUILD a circuit. A circuit is very, very important to electrical things like flashlights because…well, don't worry about that just now. The important thing is that each time you visit an inventor, he will give you some important information about a part of a circuit. Listen carefully, because he'll ask you some important questions about that part. If you answer the questions successfully, you'll get the part to place in your TOOLKIT (*toolkit blinks).* Then you'll activate the time machine controls again and go collect another part of the circuit. Once you have all the parts, the time machine will bring you back here and I'll show you how to put them together to build the flashlight. THEN you can go outside and find Tess Thanks for you help! Good luck!

The screen fades out to static. Then the student can activate the time machine's controls. After the student does so, year numbers begin to roll backward on the screen, starting from 2006 and ending with 1782.

Script 2 – What is Electricity?

Benjamin Franklin: Oh, hello! Who is there? I see something here, but it's not exactly clear. *Screen clears.* Hello! Dr. Potts told me you would be coming. You've traveled here in your time machine, I suppose. And by HERE I mean the year 1782. I'm happy to make your acquaintance. I'm Benjamin Franklin.

Puppet bows. As he does so, he startles.

Oh, my, what has happened to me? Why do I look so strange? I shouldn't look like this at all. I should look like *(screen image fades to regular picture of Benjamin Franklin* THIS. (*Screen image fades back to finger puppet).* Ah, well, it must be the transmission of the time machine. Dr. Potts warned me that might happen. We'll just have to go along.

As I was saying, I'm Benjamin Franklin. You might have heard of me. I lived many years past from your time. I was born in 1706 (about 300 years ago), and was known to be a revolutionary of sorts. One of the founding fathers of the country, you know. And for good reason, too. I don't mean to brag, but I'm an author, a philosopher, an inventor, and a diplomat. Don't worry too much if you don't know what all those things are…you will.

Appendix B

Scripts

Today, though, I want to tell you the story of what I discovered about electricity. Have you ever been out in a thunderstorm? I'll be you have. And so I'll be you know about lightning. I noticed that lightning flowed from place to place and so thought it must be some kind of electricity. In those days, we didn't know much about electricity – what it was or what you could do with it. In your day and age, you have many inventions that run on electricity – lamps and computers and even some cars. In my time, we don't have those things. I know about them because I've seen into the future with Dr. Potts time machine, but I'm not supposed to tell anyone!

Back to the thunderstorm…I reasoned that if lightning was electricity, I could get it to flow down the string of a kite. So I did what you might call the CRAZIEST thing. I tied a key to a kite string, and flew the kite…DURING A STORM! Wow! The lightning struck the kite, went through the key and the string and into my hand! I was lucky I wasn't killed! Kids, don't try that at home!

But I proved that lightning was electricity. So I've recently begun thinking about just what electricity is. Now, in my day and age we don't have the tools to figure this out, but Dr. Potts has told me that they have powerful microscopes in the future that can see the smallest parts of things. And they have discovered that all things are made of tiny building blocks called atoms. Look around you! Everything is made up of atoms! Your finger is made of atoms! Your chair is made of atoms! Even the air you breathe is made of atoms!

Screen switches to an animated graphic of an atom.
Inside each of these atoms are tiny parts that make up the atom. In the middle there is a center part called a "nucleus" which contain tiny parts called protons and neutrons. Whizzing around the nucleus are even tinier parts called "electrons". Sometimes these tiny electrons break free and flow away from the nucleus of the atom. When that happens, you get electricity!
Screen switches to a picture of lightning striking Franklin's kite
Electricity can happen in nature. Remember that lightning is electricity? But to have a steady flow of electricity, you need something that can produce electricity reliably.
Screen switches to a picture of a battery
Batteries can produce electricity, like the battery used to power a flashlight, or a car's battery. They do this by using chemicals on the inside that make the electrons break free and start to flow. Electricity is energy, and energy can be stored inside of chemicals. When energy is stored inside of chemicals, it's called chemical energy. When the chemicals release the energy it's transformed into electrical energy.
Screen shows text of transfer of energy.

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What happens to the electricity in the battery? Well, have you ever noticed how batteries have two ends? *(Show actual battery)* We call these ends "terminals". One of the ends has a negative charge and one has a positive charge. If you look closely at a battery, you might see that the ends have been labeled with a "-" on the negative terminal and a "+"on the positive terminal. Electricity flows OUT of the negative terminal and into a wire. Electricity flows through the wire and back into the positive terminal of the battery, in a circle pattern. Come to think of it, we call this pathway a "circuit"! Sounds like the word "circle", don't you think?

If you remove a battery from an electrical circuit, you lose the source of electrical power. Without a battery, this light in a flashlight wouldn't light because it would have no electricity!

Now, I hope that you are ready to take the first *Challenge* to try to earn your battery. Carefully read and consider each of the following questions. You must get them all correct to earn the first part you need to build the circuit for your flashlight, which is a battery. If you make a mistake, try again. Good luck!

Script 3 – Does Electricity Flow?

Caracatus Potts: Hello again! How was your conversation with Benjamin Franklin? (*look left*) I see you have the battery! Excellent! You've done well!

But a battery is far from a circuit! All it can do is provide the electricity required in a circuit. But there's much, much more to it than that!

For example, did you know that electricity can flow, like water? *Caracactus holds up a pitcher of water and pours it into one end of a copper pipe, which then empties into a bowl.*

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Although you should NEVER mix electricity and water (THAT would be shocking!).

But electricity and water DO share something in common – both flow through things. Like water flowing through a pipe.

Now both water and electricity can flow through this pipe – but for different reasons. Water can flow through it because it is hollow – like a hose or straw (*look through pipe at camera*),

but electricity can flow through it because it is made out of metal – copper to be exact. And instead of flowing in the hollow part in the center (like water would), electricity flows through the actual material – the copper. This is how wires work.

If electricity flows through something easily (like a wire), we call that thing a conductor.

If it <u>doesn't</u> flow easily through something, we call that thing an insulator.

Insulators might be things like rubber - like a rubber ball (*bounce ball*), plastic (*show Frisbee*), or paper (*hold up paper).*
Conductors might be things like a metal fork (*show fork*), a piece of copper *(hold up pipe)* or even water.

So if you're in a swimming pool and there is lightning nearby, you need to get out of the pool – because if the lightning strikes something, it can flow through the water to reach you.

Now, in order for your battery's electricity to flow through a circuit to the light bulb, it has to have something to flow through – think of it as a "roadway" or "path" for the electricity.

That's why most circuits have wires made of metal! (*pick up wire*)
Wires contain metal – usually copper, and so they allow electricity to flow through really, really well.

They also usually have a coating of plastic or rubber on the outside (which are insulators), so that you can touch the wires and not get zapped.

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Remember, if it lets electricity flow through, it's a CONDUCTOR, and if it doesn't, it's an INSULATOR.

Now it's time for you to earn the wire for your circuit. But to do so, you have to answer the questions in the next *Challenge.* Remember, Tess is depending on you. Oh, poor Tess! She's afraid of the dark! Hurry! Good luck!

After questions
Excellent! Now that you understand about conductors and insulators, you can take some of the spare wire that I keep in the time machine. You're doing great!

Now you can activate the time machine's controls to visit one more famous inventor from the past. Have fun!

Script 4 – What Can Electricity Do?

Thomas Edison: Greetings! My good friend, Caracatus Potts, told me you were coming. Seems like I'm to help you build a circuit to make a flashlight so you can find Caracatus' cat, Tess. That appears to be a very complicated way to solve the problem, but then that's Caracatus for you.

I'm Thomas Edison. Pleased to make your acquaintance. And you are? Oh, that's right, I can't hear you – only you can hear me.

Well, as I was saying, I'm Thomas Edison. You might have heard of me. I'm an inventor, an inventor who has made a real difference in your life, I'll bet. For instance, do you like to go to movies?

Of course you do! Well, I invented the first movie camera that led to your modern movies. Do you like to listen to music?

I was the first person to capture and record sound, so I'm kind of the great great grandfather of your IPODs! Do you like to go places in your car? I invented the first electrical battery for cars!

Today, though, I want to talk to you about one of my most practical inventions – light bulbs.

Actually, that's not totally truthful. I didn't invent the light bulb, you see. The first light bulb was invented by Humphry Davy, and English scientist in the year 1800. But that bulb, and several others that came later, couldn't burn for very long. I was the first person who created a light bulb that could burn for over 60 days. I'm particularly proud of that!

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So I'm a really good person to explain to you how a light bulb will work in your circuit. Listen carefully so that you may earn the light bulb for your tool kit.

Light bulbs are pretty simple. Inside of the bulb is a wire called a filament. Recall that electricity is flowing electrons. As the electrons flow through the filament, they are constantly bumping into the atoms that make up the filament. The electricity makes the atoms heat up. If the atoms are heated up to about 4,000 degrees Fahrenheit (that's 3 times the temperature of a candle flame), they will actually give off light.

Have you ever noticed when you touch a light bulb that has been turned on for awhile that it's hot? Now you know why. The electrical energy has been turned into heat and light energy. Did Caracatus teach you a scientific law that talked about that? Can you remember the name?

It's the *Law of Conservation of Matter and Energy (blink text).* What a great law! It says that energy can't be created or destroyed – only changed from one form to another.

Remember when the battery changed the energy from chemical energy into electrical energy? Now the light bulb changes it again, this time from electrical energy into heat and light, also forms of energy (*Text: electrical energy → heat, light energy).*

So now you see how the light bulb works and why I think it's a great invention?

Light bulbs are called "loads" when they're on a circuit, because they use electricity to do a job. Their "job" is to produce light. But they're not the only types of loads. Anything that uses electricity in a circuit to do a job can be a load – a doorbell uses electricity to make the noise that lets you know someone's at the door; your refrigerator uses electricity to keep your food cold. Many other things use electricity, too.

Let's have some fun! Since you're in a time machine, let's look at some pictures of important inventors of the future from the time machine's computer.

Oh, I recognize her! I have a confession to make! This isn't the first time I've played with Dr. Potts time machine. So I've seen this person before. She's the famous Dr. Keisha Manchester, credited with inventing the very time machine you're standing in. It runs on a series of circuits, you see.

And this is Dr. Vera Courtney, as a child, of course. She doesn't know it here, but she will grow up and invent the first intergalactic space rocket that will take us into another galaxy. Also runs on sophisticated circuitry.

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Now it's time for your next Challenge. If you're successful and answer all of the questions correctly, you'll see a light appear in your tool kit.

Good luck!

Segment 5 –The Circuit

Caracatus Potts: Oh, you're back! (*look left*) And you have the battery, the wire, and the bulb! Excellent! Now all you need is a switch, and you'll be able to assemble the circuit for the flashlight, explore the cave and find Tess! Let's get started!

Remember how Benjamin Franklin told you that a circuit is a pathway for electricity, and that the electricity goes around in a circle? Let's look at this completed circuit to see how that works.

(*Point to parts of model*) Recall that the energy starts as chemical energy in the battery. Now don't be alarmed – this battery looks a little different because both terminals, the positive and the negative are on the top, instead of one on each end – but it works the same otherwise.

Anyway, the chemical energy is changed into electrical energy that flows out the negative (-) terminal of the battery and into the wire (a conductor).

It flows into a light bulb and is changed into heat and light energy by the bulb.

Then it flows back into another wire, and into the positive (+) terminal of the battery, completing the circular pattern of the circuit.

The light will stay lit as long as this flow continues.

But what if the flow was interrupted, or stopped? The light would go out because the electricity couldn't flow through the entire circuit.

That's how a switch works! If the switch is up, the electricity can't get across this gap of air and into the wire, so the light goes off (*show on model*). We call this type of circuit an OPEN CIRCUIT.
If the switch is down, the electricity can flow through the metal of the switch and continue its path to the light bulb and back to the battery. We call this type of circuit a CLOSED CIRCUIT.

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On! Off! Closed! Open! (*Throw switch open and closed*)

And all done with a simple…switch.

Now here's a good way to really see the difference between a conductor and an insulator.

The metal of the switch is a conductor, so when the switch is down the electricity can flow through the entire circuit (*show*). When the switch is up the electricity can't flow through the air (because air is usually an insulator).

So we can try putting a few different materials in this gap to see if they are conductors or insulators. (Keep in mind that this is safe only because this circuit has a very low voltage – 6 volts. Never try anything like this without an adult around.)
Now - watch what happens when I put this copper pipe across the gap – the light goes on! That's because copper is a conductor!

Now watch what happens when I put this rubber ball across the gap – nothing! The light doesn't go on because rubber is an insulator.

What about the plastic Frisbee? Nothing.

Now - what about the fork? Do you think the light will go on? (*show*)

If you said it will – you're right! Like the copper pipe, it's also made out of metal, so the electricity can flow through it and all the way through the circuit.

Now it's time for your last challenge questions. Again, you must get them all right to earn the last thing you need for your circuit – a switch.

Good luck!

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Segment 6 – Assembling the Circuit

Great job! Now you have all of the parts needed to make a flashlight.

Now it's time to put it all together! You're finished flashlight will look something like mine. I know, it's a little big and doesn't look like a normal flashlight, but it works.

You'll be asked some questions, and you must assemble the flashlight circuit by picking the right items from your toolkit or answering the questions.

Succeed, and the light in the flashlight will come on and you can enter the cave to look for Tess.

Oh, poor Tess, I'll bet she's hungry by now. Good luck!

Segment 7 - Finale

Caracatus: Oh, you're back! (*Look forward and down*)

And you have Tess!
Oh, I'm so happy – I can't thank you enough!! (*look forward and down*)
Tesla Time! You're so adventurous.

Wow – your flashlight must have worked perfectly for you to see in that dark cave.
You should be proud of yourself – you put together a working electrical circuit from a bunch of spare parts!

Maybe you'll be a famous inventor one day too.
Hmm… maybe that's why Tess wanted to go to your time… you do look a little familiar… what was your name again?

Anyway, now that Tess is back in the machine, all you have to do is activate the time machine one more time and run quickly out of the door.
Tess and the machine will then return back to my time – safe and sound.

Thanks again, and maybe we'll meet again some time!
Victory dance