Product testing Circuit Scribe

Introduction

Teaching electricity and electronics is often very teacher-centred, perhaps due to the problems with the equipment, and as a result students can become disengaged. When I stumbled across Circuit Scribe, I decided it could be an engaging student centred approach to teaching the fundamentals of electricity and electronics and that the experience was worth documenting.

Circuit Scribe equipment (pictured below and in appendix 2) utilises a new conductive ink and magnetic components to build circuits. Using Circuit Scribe book and pen, complete with conductive ink, students are able to draw circuits in their books and then connect the magnetic components to make them work. The pre-made workbooks guide the students through the use of different components. The company continues to grow its product; since we purchased the equipment, Circuit Scribe has developed a set of online resources that are compatible through google platforms

As a teacher I was fundamentally interested in whether my students would find the equipment engaging and whether it could be used to enhance my curriculum.

Figure 1: A light control motor that is utilising a NPN transistor to amplify the sensor output

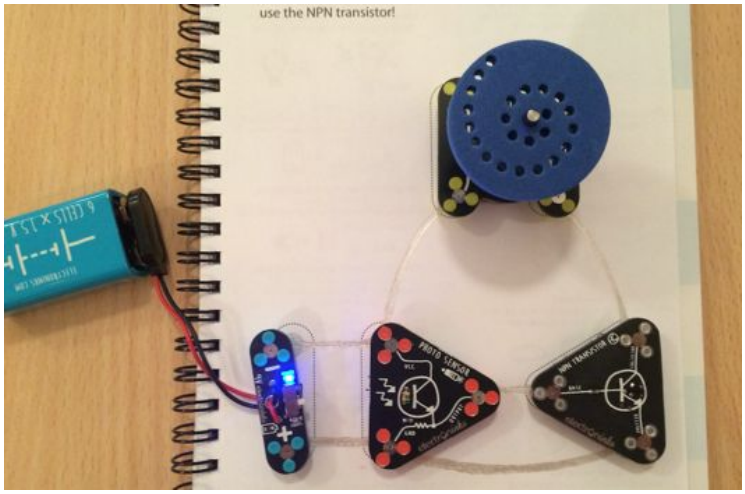
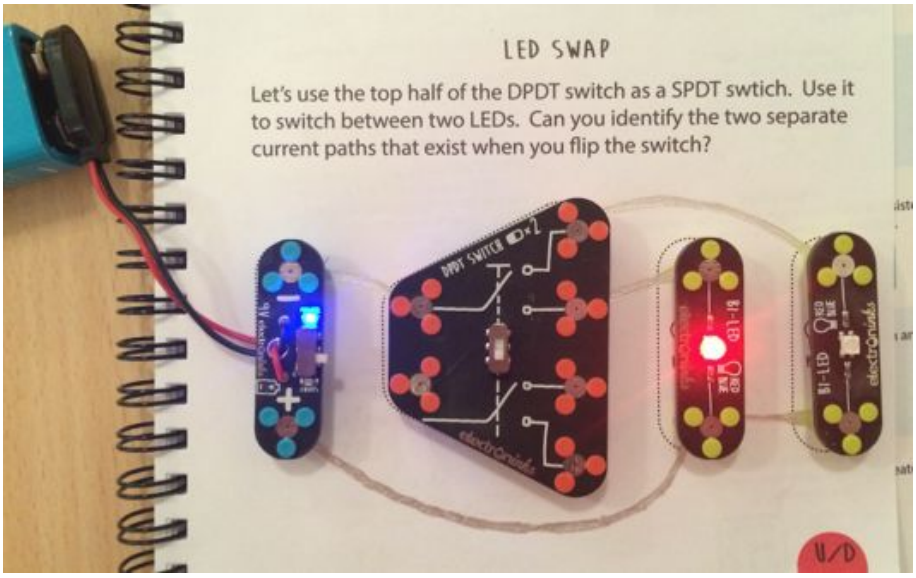


Figure 2: A circuit using a single pole, double throw (SPDT) switch to control the LEDs



Participants

Class	*Number of classes*	*Students per class*	*Grade*	*English level*
ESL 2 Physical Science	2	16 total	10 and 11	ESL*
Physics	1	12	10	Mainstream

* English as a second language (ESL) program is for students who tested below 81 in the CEFR placement tests. The course is designed to develop the students linguistically whilst also teaching them content

Approach

I tested the equipment with two types of classes, two English as a Second Language (ESL) classes and one mainstream class. In the ESL classes, I addressed the following questions:

1. Are the workbook and the kit alone enough to engage students and teach them the fundamentals of electricity (with no additional outside input)?
2. Do students find the equipment engaging?
3. Is Circuit Scribe accessible for ESL students?

In the mainstream class, I gave students more free reign than in the ESL classes. I asked them to complete three projects of their choice from the online simulator. I had already taught them

about the principles of electricity and wanted them to compare the use of the standard bulb-and-wires to the electronic ink of Circuit Scribe.

ESL Methodology

To test the product, I used two ESL 2[1] physical science classes as test groups. As a preliminary study, my main aim was to gauge student engagement and gather their - and my - opinions about the materials. Students were given the equipment complete with the workbooklet, a set of supplementary questions (Appendix 3) to gauge their learning at each stage, and six lessons totalling 4.5 hours of work. In addition, students were given a pre and post quiz (using mini white boards to display their answers) to indicate their learning.

Mainstream Class Methodology

By the time I used Circuit Scribe with the mainstream class, the Project Ignite website was available and a set of resources that utilised the circuit scribe online simulator had been developed. I had already taught the students the principles of electricity with wires and bulbs and wanted to see if they could apply this knowledge to test some lessons about series and parallel circuits, and introduce the field of electronics to them.

Students were given a set of the equipment and invited via Google Classroom to complete a set of eight lessons through the Project Ignite interface, culminating in a project making a pressure sensitive alarm system. Students were then asked to select additional lessons of their choice.

Findings

From the teacher's perspective

It's first important to clarify the difference between electricity and electronics. Teaching the principles of electricity involves illustrating the concepts of 'flow of electrons' and how current, voltage, and resistance changes between series and parallel circuits. Electronics is based on functional components, such as transistors, and is the science of how to control electric energy - energy in which the electrons have a fundamental role.

Initially I used the equipment with the workbook and at first students found it very novel and engaging. The workbook is clearly constructed and builds in complexity with a level of English that is accessible to ESL students. However, after a period of time the novelty of conductive ink wore off and I was faced with the same motivational issues as usual.

I had much more success with the online simulator, which also had applications for integrating Arduino and computer programing, a direction which seems to have lots of potential. Students

[1] LAS has three levels of ESL instruction, of which ESL 2 is of course in the middle.

liked being able to first construct the circuit online, trouble shooting it before actually drawing it. In some cases they preferred the online construction so much they didn't want to draw it afterwards!

I was also interested whether this equipment could be used to teach the fundamental principles of electricity because it is common for the wired circuits to create a lot of problems, which can then quite quickly lead to disengaged students. The biggest problem that I faced was using voltage and multimeters to illustrate how current and voltage changes. It was an arduous task to teach the students how to do this and in the end I found that the problems created by using the equipment outweighed any benefits. Therefore, I was unable to teach the difference between current, voltage, and resistance across series and parallel circuits. Furthermore, when asked, 83% (10/12) of mainstream students prefered to use the traditional wire and bulbs to build circuits.

The fundamental problem that was a running theme with both ESL and mainstream students was the reliability of the pen. Although it does work, the students have to draw thick lines and sometimes re-trace the circuit to get it to work. This was reflective of the problem that led me to try this kit, technical issues (such as electrical faults in the wiring of circuits), so as a teacher if I was to weigh up the cost of the pen vs the cost of a wire I would choose the traditional approach of wires and a bulb.

From the students' perspective

Students found the equipment easy to use and interesting. One student reported "This equipment is so creative and artistic, which makes it more fun. Fantastic!!" Out of the 16 ESL students questioned, 81% (13/16) found it easy to use and 69% (11/16) said they would like to learn more about electronics. In the mainstream class 83% (10/12) wanted to learn more about electronics after using it.

Universally the students found that the pen wasn't very reliable. To quote a student: "The constant need to draw a new circuit made the process feel extremely tedious." The pen sometimes didn't work or the flow of ink was sporadic, which resulted in breaks in the circuit which were hard to identify. This led to me being more involved than I should have been, helping students problem solve or else risk losing their engagement. As suggested by one student, this problem would be solved by "instead of having a conductive pen, having a conductive marker."

The majority of students (ESL class 56% (9/16) and mainstream class 86% (10/12)) felt they worked better with a partner, but many students commented that they would have liked to work individually with their own equipment. From my own observations, I found that students were able to problem-solve much better when working as a pair than individually. However, I found it much more rewarding for the students when they each had their own pen and workbook but

shared the components. When students shared a workbook and pen. one student would often not be doing anything and this in turn resulted in them being off task.

I used the workbook provided and 75% (12/16) of students felt that the English used was accessible. However, key technical terms did need to be translated and better defined for the students. From observations and pre and post quizzes I found that students weren't able to gauge the key concepts of electricity from using the workbook and the equipment alone. For instance, students were able to observe that a complete circuit was needed to make a circuit work but they couldn't discern that it was due to a break in the current. I tested the equipment with multimeters to see how easy it was to measure current and voltage in order to see if I could develop a set of worksheets to enhance the start of the booklet to teach students the fundamental concepts about current and voltage. However, it proved difficult and very intricate and, again, not an advantage over the standard bulb and wires.

Conclusion

To further this study I would look at using the equipment after teaching electrostatics and building electrical circuits. I would not use it to replace the bulbs and wires I currently use to teach current, voltage, and resistance in series and parallel circuits. However, I will be looking at developing a set of resources that could be used for two lessons as an introduction to electronics. Furthermore, the equipment is compatible with Arduino equipment so it could act as a platform to introduce students to using Arduino to build circuit boards and basic computer programming.

In conclusion, the equipment is novel and exciting. However, although it is possible to make the pen work, the unreliability of the pen, requiring the students to draw thick lines and sometimes re-trace the circuit to get it to work, is a serious problem. This was reflective of the problem that led me to try this kit, technical issues (such as electrical faults in the wiring of circuits), so as a teacher if I was to weigh up the cost of the conductive pen and accessories versus the cost of a wire I would choose the traditional approach of wires and a bulb.

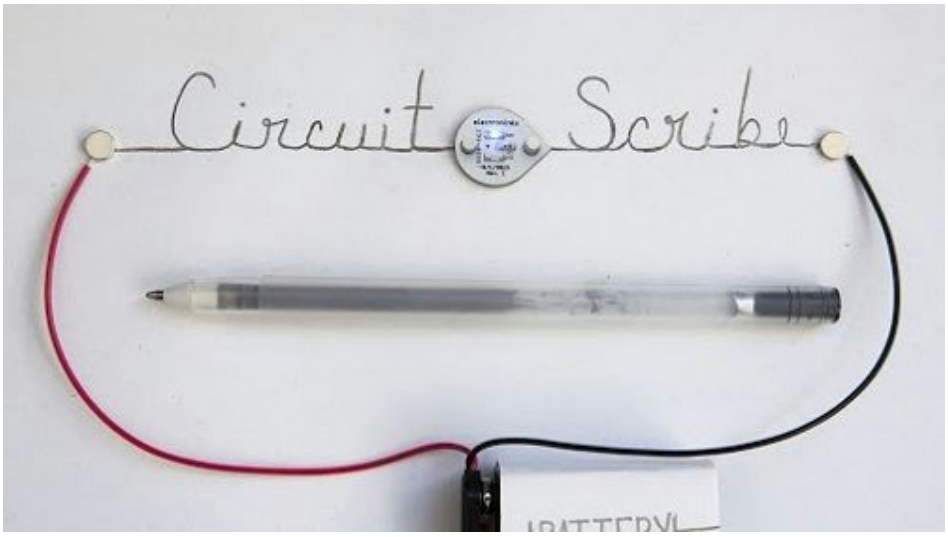
Appendix 1

Link to the circuit scribe workbook

Appendix 2

Equipment

The equipment was purchased from circuit scribe. The products I used were:
The Maker Kit (pictured below) Cost $80 approx



Appendix 3

Supplementary Questions used to support the workbook with the ESL classes.

Page 2 +3. What does the pen ink act as in the electrical circuit?	
Page 4. If you drew a circuit with a gap in the ink what would happen? Try it What does this tell you about electricity?	
Page 5. Describe what an electrical current is ?	
Page 6. Create the circuit and test all the different materials? What do all electrical conductors have in common? Why do you think that is?	
Page 7. What is resistance? How is resistance measured?	
Page 11. Draw a circuit diagram with a switch and a LED in	
What is an LED? How is an LED different to a bulb?	
Page 12. What is the difference between a series and parallel circuit? Sketch and example of each	

What are the circuit symbols for; 1) A bulb 2) A LED 3) A resistor 4) A battery (sketch them)	
Page 12. What is the difference between an 'and' gate and an 'or' gate. Sketch an example of each	
Page 11. What is a SPST switch? What examples can you think of in everyday life What is the symbol for a switch?	

Page 13. Sketch the circuit that has a DPDT. Identify the two separate current paths that exist.	
Page 14. When might a DPDT switch be useful?	
Page 15. What is a transistor? When you added a transistor to a circuit what effect did it have? When would you use the NPN transistor?	
Page 16. Create the circuit, how were you able to act as the switch? Which component was essential for this?	

Page 17. How does a buzzer work?	
Page 18. What does the motor convert electrical energy into?	
Page 19. Draw a circuit that will allow you to operate each colour of the RGB LED separately.	
Page 21. What is a potentiometer? When would it be used? What is its symbol?	
Page 22. Draw a circuit diagram with a variable resistor, LED and battery	
Page 23. What is meant by the term ‘active module’?	
Page 23. How does a photo sensor work?	

Page 24 -5. How did the photo sensor effect the LEDs? The buzzer? The motor?	

Page 26-7. Make the circuit on page 27, how did the blinker effect the two LEDs? Did they turn on and off at the same time?	
Describe how blinker module works.	