AMN10 Rotorua school outreach. FLEET-led workshop evaluation

Workshop objectives:

- For students to understand the basic types of energy, electricity, circuits, resistance and the concept of conservation of energy
- For students to understand the difference between kinetic and potential energy
- Increased awareness among students of FLEET research, to get them thinking critically about FLEET's research problem and how we value digital technology.
- To have students thinking critically about society's use of energy
- *Increased student awareness of nanomaterials and their properties
- **Increased student awareness of the breadth and depth of opportunities in STEM

*These workshops were led by MacDiarmid Institute members and not formally evaluated for this report.
** MacDiarmid Institute members organized and conducted this student career workshops for senior students. Student met scientists and learned about their careers and career paths. Again, this was not formally evaluated except observation and some teacher feedback.

Highlights

- 320 years 5-9 students participated in a variety of hands-on science workshops
- Evidence of student learning and engagement with physics
- 25 FLEET and MacDiarmid volunteers getting experience in communicating physics to a student audience

Method

The following method applies to the three FLEET-led workshops: catapults, balloon rockets and graphite circuits. Each workshop was divided into four broad components: a pre-evaluation exercise that determined students initial understanding of either energy (catapults and balloon rocket workshops) or electricity (graphite circuits workshops); a short introduction to introduce students to the scientific theory that underpinned the hands-on activities; hands-on activity and role playing; a post-evaluation/reflection session to assess learning.

The emphasis was on the workshops' hands-on component. We did introduce students to FLEET and MacDiarmid Institute's research that related to efforts to develop materials to make digital technologies more energy efficient, but it tended to be brief because of time constraints. Where appropriate, volunteers could elaborate on this with students during the hands-on activities.

The method specific to each of the three FLEET workshops is outlined below.

Catapult

This workshop used the catapult described in the FLEET Schools' resource: https://www.fleet.org.au/blog/catapult/

Introduction: At the beginning of the workshop students were introduced to the concepts of kinetic and potential energy, and the transfer of energy using the ball drop demonstration. The ball drop demonstration involves placing a tennis ball on top of a basketball and dropping the two from a height simultaneously. This was followed by a brief description of what energy is and how understanding it helps us understand how every component of the universe works.

We briefly introduced FLEET's research and the motivation for this research, which was framed around the problem of the increasing energy consumption of digital technologies.

Hands on the catapults
We had a short discussion with the students to examine the different components of the catapult and got the students to indicate where the different forms of energy (potential elastic energy, kinetic energy) were in the catapult. Because of the short time frame, the catapults were pre-built for the students.

Working in teams of 2-3, students had to apply the physics of potential elastic energy stored in the rubber bands and the icy pole stick, and the effect of different fulcrum points to do three tasks:

1. Students had to adjust the fulcrum point of their catapult and observe the height and distance their catapult flung their projectile.
2. Students modified their catapults to produce a desired effect, in this case flinging the projectile a greater distance.
3. Student had to come up with a prediction/hypothesis for what their modification would do, test that idea and observe the effect.

A competition was held between the teams to determine whose modified catapult could fling a projectile furthest.

Balloon Rockets

This activity is based on the FLEET home science activity found here:
https://www.fleet.org.au/blog/balloon-rocket/

Introduction: The basic setup is an inflated balloon attached to a straw that can run along a string when the inflated balloon is released. Students had to consider where the potential and kinetic energy existed in the balloon rocket system before and after the release of the balloon. The students were introduced to Newtons 2^{nd} and 3^{rd} laws asked to think about how they applied in the balloon rockets.

Hands on the balloon rockets
Students used the vertical rockets (the string was attached between the floor and ceiling/rafter for the vertical rockets). Students added increasing amounts of weight to the vertical balloons until their balloon would no longer leave the floor. They were given the scenario that this weight was the weight of the astronauts and their scientific equipment necessary for their journey into space. It could not be reduced. What could they change about their balloon rocket to ensure their rocket could once again get into space (top of the string). They were asked to consider the element of force, mass and acceleration where mass was fixed, and acceleration was currently zero and needed to be above zero.

Graphite circuits

The workshop is based on the graphite circuit activity from the FLEET Schools resource.

Introduction: Students were introduced to the atom and its main components: the proton, neutron and electron. The role of the electron in generating current was explained. The concept of resistance was also explained.

In the first graphite circuit workshop we attempted to conduct a role play activity to demonstrate resistance. The workshop had more than 40 students and we quickly discovered that such an activity was unworkable with such a large group and a shorter and simplified version was used for subsequent workshops. In these subsequent workshops the exercise was also conducted after the hands-on construction of the graphite circuits.

Building the graphite circuits

Students constructed the graphite circuits and determined how long they could make the circuits before the LED would not work. Students were asked to consider what was happening to the LED the further it got from the battery and why it stopped working at a certain distance from the battery. They were also asked what they could change in their circuit design to get their LED to light up again (other than move it closer to the battery). Students were given the challenge to see who could make the longest circuit and still have their LED operating.

Results

The results are the pre- and post-evaluation responses from students in each of the FLEET-led workshops. The responses are grouped into broad and simple themes. The responses from the three separate graphite circuit workshops were similar and the students were in similar year levels, so these were combined and analyzed together. The catapult and balloon rocket workshops, despite the similar focus on energy and similar student age range, were distinct enough to be analyzed separately.

Table 1. Te Koutu School. Workshop: Catapults. (1 session, year 8-9). Evaluation question: What comes to mind when you think of energy? Themes are in bold

Pre-evaluation response	Post-evaluation responses
Stuff that uses energy: Phone; phone charger; electric blankets	**Energy types:** Kinetic energy; potential energy;
The obscure stuff that uses energy: Space ship; house	**What is energy:** Force; force in bounce (of ball); gravity pulling down (the ball and objects); gravity is a force
Source of energy: Batteries; solar panels; water (hydro)	**How energy works:** Energy transfer – it moves the energy;
What is energy: Lightning; food; sun	
Getting physical: Physical energy (eg, running)	

Table 2. Te Rangihakahaka School. Workshop: Balloon Rockets (1 session, Year 8-9). Evaluation question: What comes to mind when you think of energy?

Pre-evaluation responses	Post-evaluation responses
Where energy comes from: Electrical wires; power points; power lines; solar panels	**Stuff that uses energy:** Rockets

Stuff that uses energy: Cars; light bulbs	**How energy works:** Gas/air converted to energy
Getting physical: Running; exercise	**What is energy:** Gravity
Source of energy: Food; sun; water generators	
What is energy: Electrical; lightning; thunder; solar system	

Table 3. Rotorua Primary School and Whangamarino Primary School. Workshop: Graphite circuits (2 sessions, years 5-6) (1 session, years 5-7). Evaluation question: What comes to mind when you think of electricity?

Pre-evaluation responses	Post-evaluation responses
Outcomes of electricity: Sparks(2); shock(2); pain; buzzing sound; electricity(2)	**Circuit components**: Coils; computer chips; microchips; copper; plastic insulators; powerpoints; Wires – making sure power gets through
Stuff using electricity: Light(2); electric car; electric motor; electric ball; electric dice; lasers; electronics; devices; TV(2); lights; photos – taken with iPad; games; air-con; microwave; Game Boy; Play station; Laptop; PC, electric fence; fun – play with it, makes phones, etc	**Quantum and atomic**: Neutrons; electrons(2); atoms(2); positive and negative; micro – waves (ie electrons are small waves)
Generation, source/transmission of electrical energy: Battery(3); power source; (power) cords; sun(2); solar panels	**Thinking about the graphite circuit:** Had to make pencil lines darker to make it (circuit) work; power travelling through circuits to power light; closer to the battery = more light; wires and graphite; pencil; electrical circuits
What is electricity: Lightning; energy; power(2)	**Thinking about resistance and energy consumption:** (Computer chips) using too much energy; computers dying because they lose heat; computers losing coolness; electrons losing energy(2); like little people walking and losing energy; electrons moving; (electrons) making a wave; electrons/power can't get through (referring to resistance); (loss of energy from electrons) produces heat
	Outcomes from electricity: On trampoline – hair standing up; getting shocks (from trampoline)
	Stuff using electricity: Sim cards; WiFi; rocket ships – Elon musk; cars; trucks; helicopters; electricity; light
	What is electricity: Lightning; power(2); energy;
	How computers work: Computer chips make the computer brain

What it all means

From a comparison of the pre- and post-evaluation responses alone, there are limitations to what can be concluded and these are outlined in the Limitations section below.

From observation, it was clear that the students actively engaged with the hands-on activities and enjoyed the experience. When we questioned students during the hands-on activity about what they were doing and whether they could explain what was happening, nearly all students made the effort to think through what they were observing and relate that to the theory provided in the introduction. Note, however, that the theory often had to be repeated here. To varying extents, students could usually explain what they were observing. For example, after some discussion and reiteration of the theory, students building the graphite circuits could explain that the reason their LED got dimmer the further it was from the battery was because the electrons were losing energy as they flowed through the graphite circuit. Similarly, students understood that mass affected the ability of their balloon rocket to lift off the ground and that to get it to take off they need to add more force. Once they worked this out and that the force was supplied by the balloon, students were observed adding extra balloons to the string or adding more air to the balloon. See Figure 1.

These observations, however, appears to contrast the pre- and post-evaluation responses for the students that did the catapults and balloon rockets workshops, especially for the Te Rangihakahaka students that did the balloon rockets. This may be because they were older students and experience suggests that older students can be reluctant to put their hand up to offer responses. FLEET and MacDiarmid volunteers noted that they heard students whispering appropriate responses to each other, but none volunteered them publicly to be recorded on the whiteboard. The lack of pre- and post-response data makes it difficult to make any strong conclusions about learning and critical thinking for these workshops, however, the observation data does indicate we had some impact on learning.

Figure 1. Students adding force to their rockets by adding extra balloons

Experience has shown that younger, primary-aged students are less inhibited and more willing to contribute their ideas in this activity. This is supported by the fact that the students doing the graphite circuit workshops were all run with primary students and there was relative enthusiasm to participate in either the pre- or post-evaluation activity. A comparison of Table 1 and 2 with Table 3 makes this apparent.

In contrast to the balloon rockets and catapult workshops run with older (middle school) students, there is sufficient data from the students who did the graphite circuit workshops to suggest that students did learn and to some extent think critically about the energy consumption of digital technologies. In the pre-evaluation responses to the question, what comes to mind when you think of electricity, students' responses could all be grouped into three main themes: Outcomes of electricity, Stuff using electricity and Generation, source/transmission of electrical energy. See Table 3. Devices that use electricity such as TVs, computers, etc made up the majority of responses. At the end of the workshop, student thinking shifted to a deeper conceptualization of electricity. Students talked about resistance and the issue of energy consumption (computer chips using too much energy; computers dying because they lose heat, loss of energy from electrons produces heat). They recalled neutrons, that electrons were like tiny waves, and that there were charged particles involved. They recalled components of the circuits and that power travels through the circuits. See Table 3. Despite the limitations discussed below, it is reasonable to suggest the workshops had some impact on scientific literacy. There is considerably less certainty though about the impact we had on students' critical thinking about the science and scientific problems FLEET and MacDiarmid are trying to solve such as the unsustainable energy use of digital technologies. As noted, however, the emphasis of the workshops was on the hands-on component. There was insufficient time to run any in-depth critical thinking activity about this unsustainable energy use of digital tech.

Teacher feedback

The following messages are from teachers from three of the school we visited.

"I would like to thank you and your colleagues for visiting Westbrook on Wednesday. It was well received and I have heard nothing but praise for what you all did with our students. The teachers found it had great value, very engaging, and pitched at the right level for the students. I would love to have been present, but I had a class of younger students to teach. But, I have been given very positive feedback from all involved. If you are able, please let your colleagues who were involved that their time and involvement was appreciated." (Westbrook School)

"Thank you all once again for the visit today, the kids loved it!" (Te Kura Kaupapa Māori o te Koutu School)

"Thank you for helping arrange this event for our tamariki. They thoroughly enjoyed this opportunity… Please also pass on my thanks to the other facilitators / scientists who did a fantastic job." (Principal, Te Rangihakahaka Centre for Science and Technology)

Limitations

Without more in-depth evaluation built into the workshop it is difficult to know how much of the post-evaluation responses were an actual shift in how students understood and conceptualized energy and electricity and how much was based on effective recall of words and concepts they encountered in each workshop.

It became apparent also that some students may not have understood everything being said to them in the introduction. In an attempt to improve students' comprehension and retention of content covered, we shortened the introduction and gave students more time during the hands-on activities. This also allowed us to increase the time students spent interacting with volunteers, who could reiterate the theory during the hands-on activity, as well as sharing more of their own individual science stories. It is unclear whether this change in format made a difference to student comprehension.

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