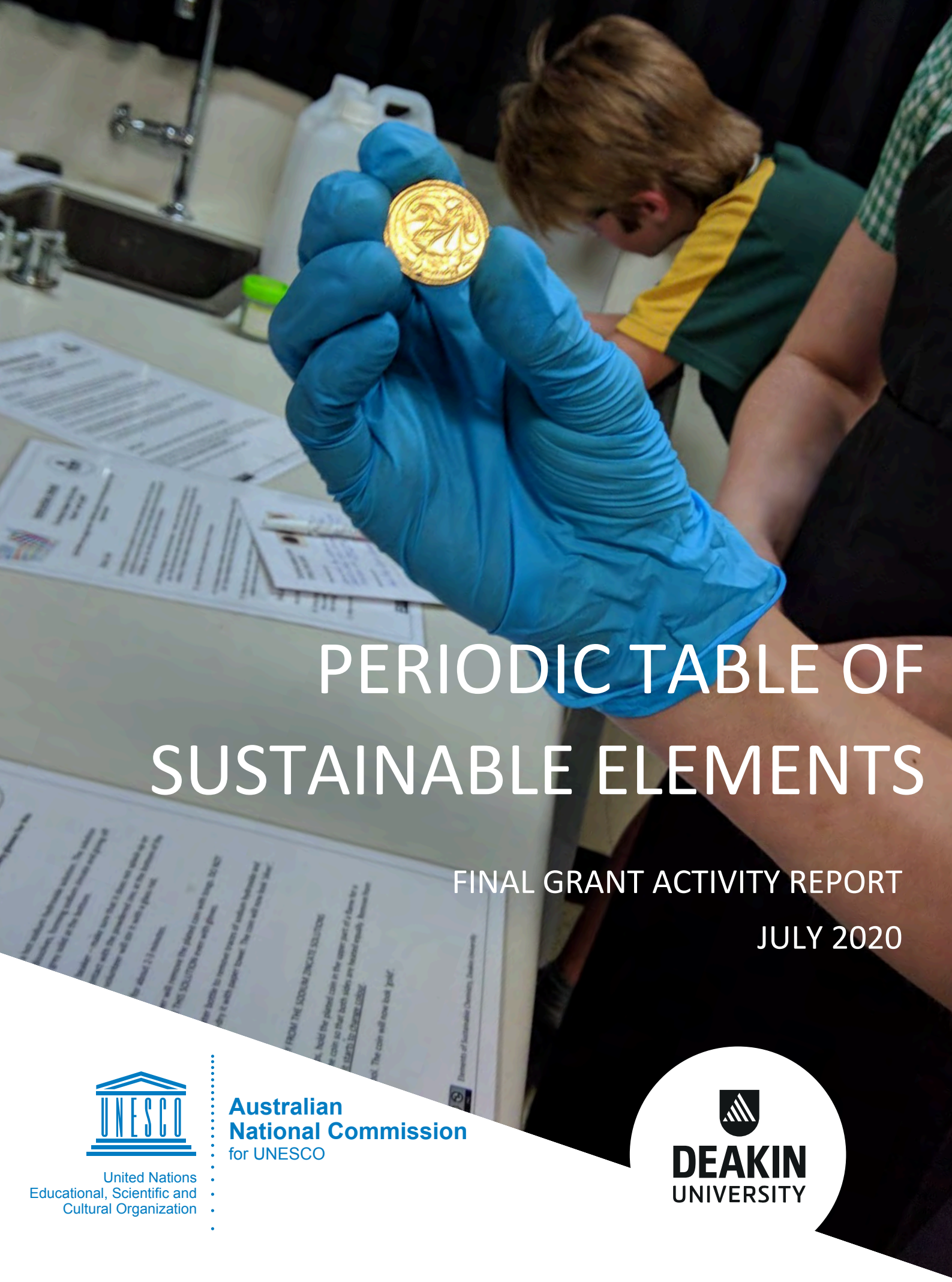


PERIODIC TABLE OF SUSTAINABLE ELEMENTS

FINAL GRANT ACTIVITY REPORT

JULY 2020

United Nations
Educational, Scientific and
Cultural Organization

Australian
National Commission
for UNESCO

DEAKIN
UNIVERSITY

> …You come along with your experiments, and they're *different* and they're *dangerous* and they're *exciting* and they're *new* and they wouldn't have seen anything like that at middle years for the students…So it was very – it was very educational, … enlightening for them, that there's more to chemistry…
>
> *Wodonga Senior Secondary College – Teacher Interview*

Periodic Table of Sustainable Elements – Final Grant Activity Report - July 2020

Prepared by Deakin University for the Australian National Commission for UNESCO
By Seamus Delaney, Joanne Jamie (Macquarie University) and Madeleine Schultz

We acknowledge the Gunditjmara, Wadawurrung, Wergaia, Dja Dja Wurrung, Wemba Wemba and Waveroo peoples, the traditional custodians of the lands and waters, on which this project took place. We respectively acknowledge the Traditional Owners of Country throughout Australia and pay respect to the ongoing living cultures of First Peoples.

Photo (cover): Turning a copper coin into 'silver' and 'gold' experiment

Photo (right): Thermite demonstration (with aluminium powder)

CONTENTS

SUMMARY

The International Year of the Periodic Table of Elements provided a perfect opportunity to implement community engagement activities that re-position the public image of chemistry, from one that currently suffers from the consequences of large-scale uptake of its previous successes such as plastic waste and polluting industrial plants, to one that has embraced the principles of sustainability. This project took the Periodic Table of Elements as an organising principle, and developed activities to increase understanding of the Table itself and the importance of chemistry to sustainability. Hands on visits at schools in disadvantaged areas allowed maximum impact on a large number of students.

Using the grant generously provided by the Australian National Commission for UNESCO, we were able to offer our 'Periodic Table of Sustainable Elements' outreach event at no cost to seven regional and rural schools, where over 1000 students took part. Over 80 of these students took part as 'student leaders', where they were involved for the whole day, either mentoring younger age school students undertaking the experiments, or being mentored themselves by Deakin university student volunteers who discussed with them post-secondary education opportunities in STEM.

Students and teachers all positively described their involvement in the free program. All resources from the events are freely available to all interested parties on our 'Elements of Sustainable Chemistry' website. We anticipate growing our outreach event to incorporate a greater breadth of experiments, so we can continue being able to demonstrate in schools the important role chemistry is taking in meeting the grand challenges of sustainable development.

Photo (below): Periodic Table of Sustainable Elements sorting activity

RATIONALE

Chemistry educators from Deakin and Macquarie Universities utilised this grant to develop hands-on activities for school children that celebrate the International Year of the Periodic Table. The activities focus on 'endangered elements', which are over-utilised in industry and in danger of disappearing within the 21st century. Through the activities, students were challenged to take a 'systems thinking' stance, and to develop an appreciation of how a 'circular economy' keeps products, components and materials at their highest utility and value. Systems thinking can also play a community engagement role in re-positioning the public image of chemistry, from one that currently suffers from the consequences of large-scale uptake of its previous successes such as plastic waste and polluting industrial plants, to one that has embraced the principles of sustainability.

This grant facilitated the development, piloting and evaluation of these educational activities in schools in Victorian regional areas of educational disadvantage. The activities were designed to be led and facilitated by high school students. At each school, 8-12 students were mentored to take leadership roles in guiding other students through the activities, increasing their participation and engagement with STEM. The combination of the leadership workshop and wider school events was expected to increase their confidence and motivation towards science. This approach is closely modelled on the demonstrated effective methods of the National Indigenous Science Education Program (NISEP), and we were in close communication with NISEP leadership throughout the project.

The activities were designed in collaboration with scientists undertaking cutting-edge chemical sciences research related to sustainability. Having both chemistry and education researchers involved not only ensured that the activities represented cutting-edge understanding of science, but also that they were high-quality, age-appropriate, and engaging. The activities highlighted that many 'endangered' elements are in fact not running out, but remain in abundance in e-waste (in batteries, phones, etc). Therefore, the project directly relates to critical challenges to sustainable development (UNESCO Medium-Term Strategy, Strategic objective 5).

Key Objectives

The following objectives were designed for the 'Periodic Table of Sustainable Elements' project.

1. Students, teachers and schools engage positively with systems thinking-oriented, sustainability-focussed, hands-on chemical science experiments.
2. Students become leaders of chemistry outreach within their own schools, potentially increasing their participation and engagement with STEM.

A **systems thinking** approach acknowledges that many of the 19th and 20th century solutions offered to society by chemistry have become our 21st century problems. Chemists need to take a systems thinking perspective to address the global, holistic, complex nature of challenges like sustainability.

PROJECT ACHIEVEMENTS

The two major achievements from this project were: a successful series of chemistry outreach events at seven rural and regional Victorian schools and; the design and implementation of a 'Elements of Sustainable Chemistry' project website.

Periodic Table of Sustainable Elements school outreach visits

Over the period of November 2019 – March 2020, seven school events were conducted over 9 days, with over 1000 student participants. We travelled over 3000 km to carry out these activities; see Figure 1 for a map showing the locations visited. Table 1 summarises the school participation.

Bellarine Secondary College, Ocean Grove	Nhill P-12 College	Brauer College, Warrnambool	East Loddon P-12 College, Dingee
Nov 14th, 2019	Nov 25th, 2019	Nov 26th, 2019	Dec 4th, 2019
Students: ~180 (Year 8) Student Leaders: 18 (Year 8)	Students: ~80 (Year 4 - 8, 12) Student Leaders: 8 (Year 8)	Students: ~150 (Year 8) Student Leaders: 12 (Year 9)	Students: ~80 (Year 4 - 8) Student Leaders: 12 (Year 9)

Wodonga Senior Secondary College	Swan Hill College	Bright P-12 College
Dec 9th-11th, 2019	Mar 2nd, 2020	Mar 5th, 2020
Students: ~230 (Year 8) Student Leaders: 9 (Year 11)	Students: ~130 (Year 8) Student Leaders: 14 (Year 9)	Students: ~75 (Year 8) Student Leaders: 11 (Year 11)

Table 1. Summary of schools visited showing dates, number of student leaders and number of student participants.

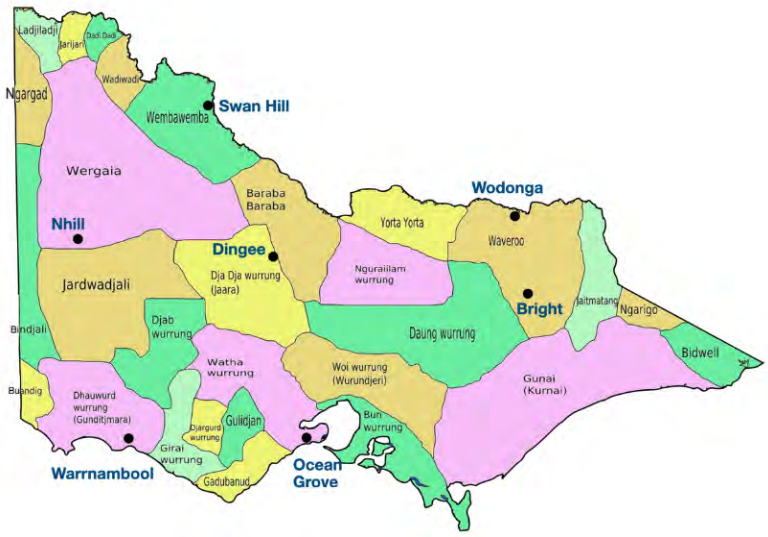


Figure 1: Victorian Local Nations map showing school locations (Credit: Tirin CC BY-SA 3.0)

School recruitment and organisation of school visits

Before contacting potential schools, approval to conduct the project was obtained from the Department of Education and Training. The process of organising school visits was as follows:

- The principals of rural and regional schools, selected due to their educational disadvantage, were contacted by email. Once organisational consent was provided, correspondence with the Head of Science established how the chemistry outreach event could be tailored for each school in terms of venue and timing.
- Once a date for the event and the year levels to be involved were established, parental consent forms were sent to each school, along with posters to advertise the outreach event in and around the school community.
- Further correspondence with the school contact was required to coordinate venue details. Depending on the school, events were run in the gymnasium, a library or a theatre stage, or in the science laboratories.
- Approval from Deakin University for all staff travel arrangements was then obtained. This included booking hotels near the school for the night before the event, and hiring of a fleet vehicle for transport of personnel and lab equipment to the school.

'Periodic Table of Sustainable Elements' outreach event

Each school outreach event differed slightly, but a typical chemistry outreach event was structured according to the following schedule:

- Deakin staff and student volunteers arrive at the school early, meet the key school contact, unload the truck and set up the chemistry equipment onto tables in the arranged space.
- Deakin staff and student volunteers then run a mentoring session with the student leaders:
  - Student leaders are shown and test all of the activities and are guided in how to provide support to student participants during the event sessions.
  - Student leaders are given opportunity to talk with the Deakin student volunteers to discuss with them their own STEM journey.
- After recess, the first event session is run with half of the student participants.
  - 5-10 min 'Introduction' seminar on the event's theme (Periodic Table of Sustainable Elements), including some eye-catching chemistry demonstrations.
  - Four 15-20 min sessions with groups of 8-12 students, who move around 'stations' to perform each set of practical, hands-on activities.
  - 5-10 min 'Conclusion' seminar, on the importance of chemistry to sustainable development, including one more explosive chemistry demonstration, and an invitation to enter the 'Periodic Table of Sustainable Elements' student competition (see below).
- After lunch, a second repeat event session is run with another half of students.
- At the end of the day, a gift of a Periodic Table is presented to the school, and we pack up, clean up and remove all waste for safe disposal.

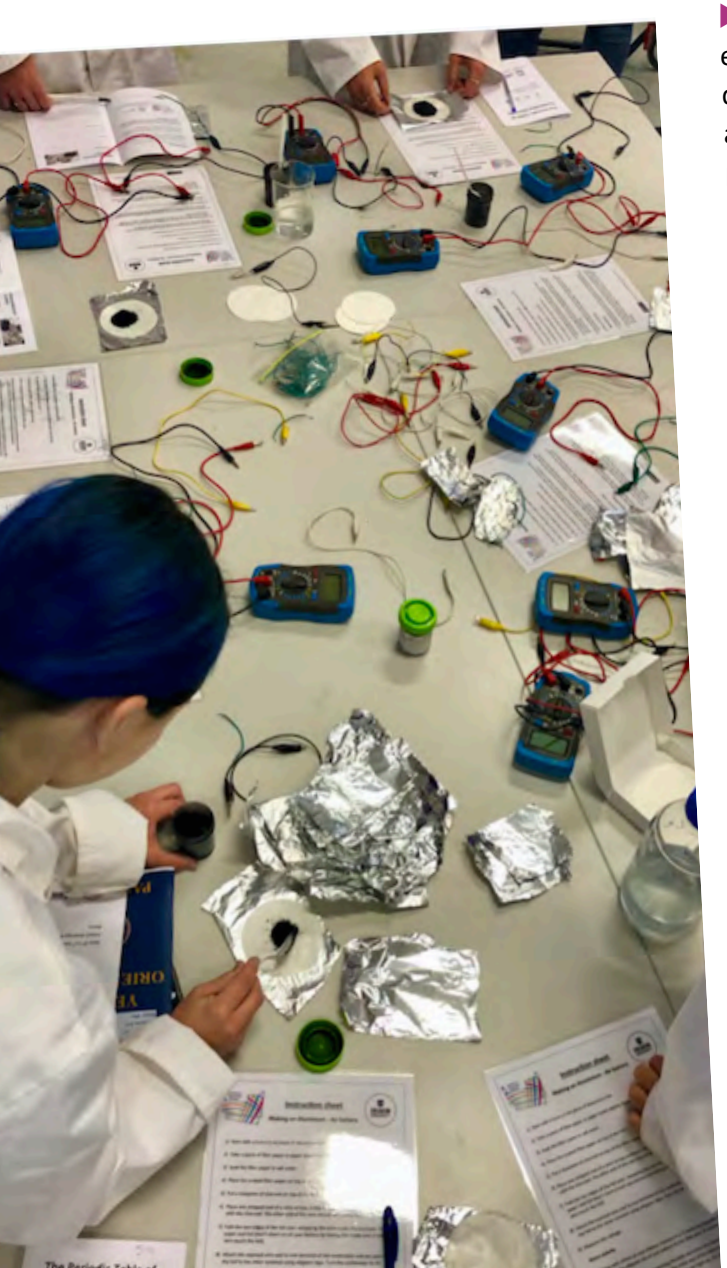
Photo: Turning copper coins 'silver' and 'gold' experiment

Design and implementation of chemistry outreach experiments

Before the school visits could be planned, considerable time was invested in designing chemistry experiments that are engaging, hands-on and can provoke further discussion around situating sustainable development in the chemistry classroom. We conducted a systematic review of the literature, and discussed with A/Prof Joanne Jamie and Dr Ian Jamie (Macquarie University) how they organise their chemistry experiments within their National Indigenous Science Education Program (NISEP) events.

An important principle in our design was that we did not want to use the standard chemistry outreach activities that many students have seen and few understand, because the chemical reactions involved are typically extremely complex. Instead, we wanted to focus on individual specific elements in their elemental form. Each of the experiments was therefore planned around at least one element of the periodic table. In most cases, the experiment challenged students to consider how this element has a significant impact on society. In many cases, these elements are now considered 'endangered' because they are over-utilised across all aspects of society and are not recycled sufficiently. For example, activities explored the chemistry of

- Zinc, which students use to coat 1 cent and 2 cent copper coins. We describe how this is analogous to how zinc is used to coat steel structures to protect them from corrosion. As such, it is heavily utilised across industry and is an endangered element could run out in 20-30 years.

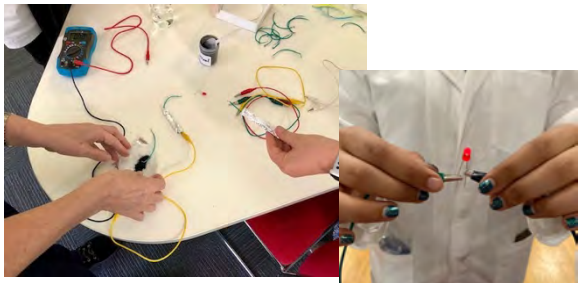


- Gallium, whose discovery helped provide credible evidence supporting Dmitri Mendeleev's Periodic Table design (Mendeleev left a 'gap' in his periodic table for an element to be yet discovered, and successfully predicted Gallium's properties based on its location in the table) is used today extensively in electronic devices. Like several other metals used in electronic devices, It has become highly endangered, as it regularly ends up in unrecycled e-waste.
- Aluminium is *not* an endangered element (8.3% of the Earth's crust). However, as a group III metal, it requires a tremendous amount of energy to produce as a pure aluminium from bauxite ore; approximately 3% of global electricity generation is used in this process. Victoria's one aluminium smelter utilises approximately 10% of all electricity generated in Victoria.

In total, 35 elements featured across the chemistry experiments and demonstrations that were developed for this project. This does not include Professor Stuart Batten's (Monash University) 'Element briefcase', generously lent to us for the school events, which contained a sample of every naturally occurring element. Few people get an opportunity to physically handle so many elements!

Photo: Students making aluminium-air batteries out of household items and electric wires

'Periodic Table of Sustainable Elements' chemistry outreach experiments



Making an aluminium-air battery

Students make a battery out of aluminium foil, wires, paper soaked in salt water and charcoal.

Turning copper coins into 'silver' and 'gold'

Students coat a thin layer of zinc on a copper coin, then heat it to turn the layer into brass

Carbon rod electrolytic writing

Students use a carbon rod attached to the power supply to 'write' brown iodine

Copper crystals growing on aluminium sheet

Students grow crystals on aluminium placed in an agar solution containing copper ions

Iodine writing and fingerprints

Students write with iodine solution, then erase with ascorbic acid (Vitamin C), and expose fingerprints with sublimating iodine

Periodic Table sets and gallium

Students sort elements on the 'endangered elements' periodic table, including gallium in liquid form

Mini-thermite reaction (with aluminium)

Aluminium powder reacts violently with iron oxide, releasing a huge amount of energy

Colourful bottle demonstrations

The traffic light reaction, the blue bottle reaction, and changing cobalt from blue to pink

Involvement of Deakin University student volunteers

An important part of the project was the involvement of undergraduate and postgraduate university student volunteers. Fourteen volunteers either attended one or more school event, or were part of laboratory preparations at Deakin University. Students were invited through online posts to Deaakin subject websites and gave informed consent before becoming involved.

A training day for all volunteers was held in October 2019, where many of the experiments were further developed. Several of the volunteers also made useful suggestions to improve the experiments. When at the school events, all of the volunteers took the time to engage with the students and student leaders, providing a valuable mentoring experience. Much preparative laboratory work was also required before and after each school event, and several volunteers also helped in this capacity.

Participation in this outreach program provided significant professional development to many of our volunteers. They developed their own leadership skills and chemistry understanding, and for several who plan teaching careers, they had valuable opportunities to interact with students.

We wish to give a big thank you to all of our student volunteers: Elley Rudebeck, Lekha Krishna, Kara Spilstead, Elisha Moloney, Stefan Bos, Tim Harte, Telisia Smith, Mikayla Milanovic, Teah Coate, Leah Cadzow, Billie Murray, Mara Macs, Faith Ukpiebo and Conner Rudebeck.

Photo: Deakin University staff and student volunteers at Brauer College, Warrnambool (left) and Wodonga Senior Secondary College (right).

Photo (above): Copper crystals growing on Aluminium sheet experiment

Elements of Sustainable Chemistry website

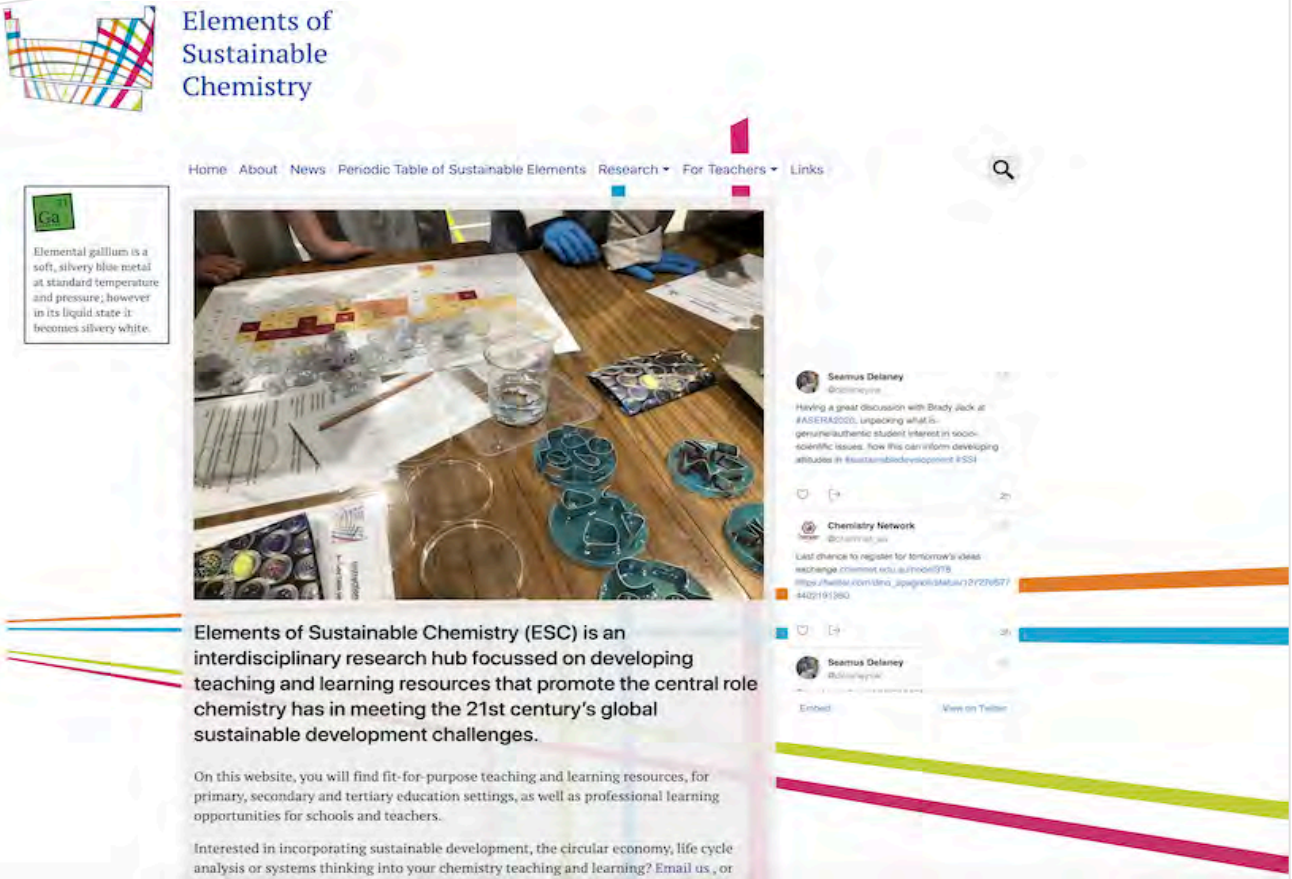
The 'Elements of Sustainable Chemistry' website was developed and implemented to support this project (http://eschemistry.org, screenshot below). While initially designed as a website to make teaching and learning resources prepared in the project available to all Victorian schools, it has grown already into an important hub for re-positioning chemistry teaching and learning in schools to address the challenges of sustainable development.

Existing features of the website include:

- For each experiment designed for the chemistry outreach event, detailed teacher, technical and student instructions (method, materials, safety considerations) are provided, to allow others to conduct the experiment in their own schools.
- PDF copies of the student and student leader booklets that were used at the chemistry outreach events. These give brief descriptions providing an authentic context to explore in terms of sustainable development and provide space for students to take notes and answer questions arising from the experiments.
- A news feed providing information on upcoming and past school events and professional learning workshops for teachers to help them incorporate systems thinking-oriented socio-scientific issues into their chemistry classrooms.
- Links to examples of practice situating sustainable development in chemistry education.

Further improvements to the website are underway, including:

- Videos for each of the chemistry experiments to further support teachers.
- New practical activities with a greater range of sustainable development contexts for future school outreach events.
- Infographics and case studies (such as wearable technologies, contemporary battery technologies) that demonstrate how systems thinking can help learners understand the role chemistry has in addressing sustainable development challenges.



ANALYSIS OF PROJECT OBJECTIVES

To evaluate the project's objectives, a systematic protocol at the school-community level is being utilised, including survey responses from students, student leaders, teachers and university student volunteers.

Data collected to evaluate the school events includes:

- Student participants
  - Pre- and post-event surveys
- Student leaders
  - Pre- and post-event surveys
- Teachers
  - Post-event survey
  - Post-interview
- University student volunteers
  - Post-event survey

Given the breadth and depth of data collected over the last few months, a thorough evaluation of this data is only beginning. Evaluation data of school outreach programs are notoriously difficult to ethically and systematically collect, and so the depth of responses collected will make an important contribution to the research literature investigating the impact of school outreach on student engagement with chemistry- focussed sustainable development.

Presented below are first 'insights' of this ongoing evaluation.

Engagement with contemporary science

Students and student leaders reported the event to be fun, engaging, hands on and different to their normal experiments at school. The chance to undertake "Experiments of the future" (Swan Hill College - Student leader post-event survey) and "…being able to do or see experiments I've only seen on videos" (Nhill College - Student leader post-event survey) were no doubt attractive features.

It was gratifying to see that students were also able to make connections between the experiments and real life contexts. The pre- and post-event surveys collected from students and student leaders contained other questions more directly about chemistry's connection to sustainable development, but comparing pre and post responses from the first two questions, "I find science…" and "I find science relevant to real life" showed a statistically significant impact on student interest and engagement attributable to the outreach event.

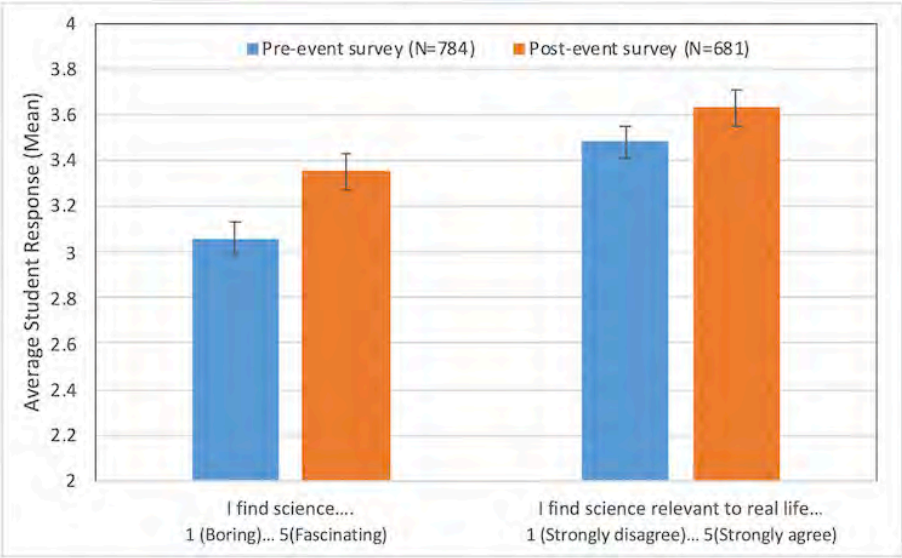


Figure 2: Mean student response for all events to two questions in pre- and post-event surveys

Mentoring of students to improve engagement with chemistry, STEM and sustainability

Student leaders consistently stated that they enjoyed the opportunity to teach others not only about science, but also about sustainability.

> "I've certainly gained more knowledge about sustainability with elements… I also loved showing it to the younger students."
> *Bright P-12 College - Student Leader post-event survey*

> "I gained confidence to help other people complete experiments."
> *East Loddon P-12 College - Student leader post-event survey*

Being able to speak and discuss with the university student volunteers across the whole day was much appreciated by the student leaders, "…because of the knowledge they shared" (Swan Hill College – Student leader post-event survey). For their senior secondary students soon to enter post-secondary education, all teachers agreed this was a fantastic opportunity, for a number of reasons.

> "And some of the senior students in particular, they liked the opportunity that they could talk to actual scientists and actual researchers and ask them questions about going to uni and what they do as well, so I found that really valuable as well"
> *Nhill College – Teacher interview*

Improved interest in science and sustainable development through school outreach

Teachers in regional and rural schools consistently report struggling to make connections between classroom teaching and learning and contemporary STEM practice happening in universities and industry. Distance and costs are regularly cited as factors limiting STEM education in these schools.

> So like cost is – cost and time is really – a real problem for our school because we are so far away from anything. We're still a good 4 hour drive to Melbourne and a 4 hour drive back and if you're only going to be there for 2 hours or 3 hours it's really not worth the time and the energy and the effort. And the students don't want to go either because it's a long day.
> *Wodonga Senior Secondary College – Teacher interview*

School outreach can therefore play a vital role in making explicit the links between the school curriculum and holistic grand-scale action taking place on sustainable development.

> "…so many other ideas to think about in terms of – even your periodic table of sustainable elements… aluminium and how much energy it actually takes in order to create (pure) aluminium and – and then it was – so it just had all these other layers in there not just about the chemistry but about also the – the humanities part to it as well. It was just so positive"
> *Wodonga Senior Secondary College – Teacher interview*

Photo: Thermite reaction between aluminium and iron oxide powders. Using only teaspoon of powder, the temperature reaches over 2500°C, but can be performed safely over a sand bath.

PROJECT BUDGET

The budget overview is presented on the next page. In summary, our major expenses were the school visits and the development of the website that was and is being utilised to support both the previous and future school outreach events.

Explanation of changes in proposed project expenditure

There were unspent project funds, principally due to the impact of the COVID-19 Crisis. Variations in the planned and actual budget items are briefly summarised below and a signed statement of income and expenditure, confirming the amount of unspent funds to be returned to DFAT, is supplied separately.

- The original intention was to invite project partner A/Prof Joanne Jamie from Macquarie University, to visit Deakin University and present a seminar on the National Indigenous Science Education Program, and to meet with colleagues to discuss the development of our outreach program. We were able to instead utilise Deakin University School of Life and Environmental Sciences funding to bring Joanne to Victoria, where her seminar was attended by a diverse group of staff including the DVC (Education), Associate Heads of School and staff from the Schools of Life and Environmental Sciences and Education. We thank the School of Life and Environmental Sciences for their funding support.
- We were able to obtain a further contribution through an internal research grant from Deakin University's Strategic Research Centre in Education, Research for Education Impact (REDI). We thank REDI for this contribution.
- Printing of student booklets and consent forms for the school visits proved to be a larger expense than planned. We did not want to pass on any printing costs to schools.
- Following government advice on how to ethically proceed with our proposed research initiative, we were unable to provide any form of financial bursary to the student leaders or gifts to local elders, so these planned expenditures did not occur. We were, however, able to provide gifts sourced from Deakin University's Schools of Life and Environmental Sciences and Education. We thank both Schools for generously making this contribution.
- We received only a very small number of entries to our planned 'Periodic Table of Sustainable Elements' student competition, where students would visualise their own Table, and winners were to be showcased on the website. In consultation with the individual schools, we decided not to proceed with awarding the student prizes. Instead, we shared photos and feedback with each school for their own purposes.
- A consequence of having less expenditure in other categories was that we were able to organise more school visits than originally planned, reaching more students and student leaders with our program.

Impact of COVID-19 Crisis on the project

The lockdown of Victorian schools and communities made it impossible to organise school visits after mid-March, 2020. We had planned to run one or two more school outreach events in April-May 2020, but instead we were left with unspent project funds.

This afforded us more time to develop further experiments for future school visits in late 2020 and 2021, and we are currently sourcing further funding.

> "Big Boom + Fire = Iron"
>
> *Wodonga Senior Secondary College - Student post-event survey*

Income	Proposed	Actual
Earned income (Salary in-kind contribution)	**AUD$ (incl. GST)**	**AUD$ (incl. GST)**
Dr Delaney salary (200 hrs, $72/hr)	$14400	$14400
Dr Schultz salary (150 hrs, $77/hr)	$11550	$11550
A/Prof Jamie salary (50 hrs, $120/hr)	$6000	$6000
Subtotal	**$31950**	**$31950**
Grants		
National Science Week grant (Note: not awarded)	$9150	$0
Deakin Research for Educational Impact (REDI) grant	$0	$3000
Subtotal	**$9150**	**$3000**
Request from UNESCO Grants Program	**$19690**	**$18150**
TOTAL INCOME	**$60790**	**$53100**

Expenditure (Items with * covered by grant)	Proposed	Actual
Salaries and fees (not covered by grant)	**AUD$ (incl. GST)**	**AUD$ (incl. GST)**
Dr Delaney salary (200 hrs, $72/hr)	$14400	$14400
Dr Schultz salary (150 hrs, $77/hr)	$11550	$11550
A/Prof Jamie salary (50 hrs, $120/hr)	$6000	$6000
Ms Jue Soo (Research assistant, 60 hrs, $50/hr)	$0	$3000
Subtotal	**$31950**	**$34950**
Travel costs		
Airfares – A/Prof Joanne Jamie Visit	$450*	$0*
Accommodation – A/Prof Joanne Jamie Visit	$390*	$0*
Accommodation – Drs Delaney and Schultz school visits	$1410*	$1570*
Car Hire – All school visits	$1500*	$1882*
Taxis – A/Prof Joanne Jamie Visit	$150*	$0*
Meals – A/Prof Joanne Jamie Visit	$150*	$0*
Meals – Drs Delaney and Schultz school visits	$1500*	$1363*
Subtotal	**$5550***	**$4815***
Overhead/administrative costs		
Postage	$0*	$40*
Stationary and printing	$700*	$1648*
Subtotal	**$700***	**$1688***
Marketing/promotion costs		
Media advertising	$400*	$0*
Printed material (flyers, handouts)	$200*	$191*
Subtotal	**$600***	**$191***
Production costs		
Website development	$4000*	$4286*
Transcription of teacher interviews	$0*	$581*
Chemical consumables for chemistry experiments	$5400*	$5700*
Subtotal	**$9400***	**$10567***
Awards, Scholarships, Fellowships		
Bursary for student leaders ($30 x ~60 students)	$1800*	$0*
Gift for community elders ($100 x ~3 gifts)	$300*	$0*
Gift for Schools ($50 x ~7 gifts)	$0*	$389*
Student prizes – 'Periodic Table of Sustainable Elements'	$400*	$0*
Subtotal	**$2500***	**$389***
Other		
Separate budget for National Science Week events	$9150	$0
Subtotal	**$9150**	**$0**
Contingency 5% buffer	**$940***	
TOTAL EXPENDITURE	**$60790**	**$52600**
	Unspent funds	**$ 500 ($454 excl. GST)**

LESSONS LEARNT FROM THE PROJECT

As part of our grant agreement, we were asked to consider some of the lessons learnt from our project, for how a similar grant activity could be better undertaken in the future. Conceptualised as 'enablers' and 'constraints', these have also informed our own future directions with this project.

ENABLERS

Embedding contemporary science

The involvement of scientists researching contemporary chemical science practice was invaluable in designing authentic practical hands on activities that represent chemistry's role in sustainable development.

International Year of Periodic Table (IYPT) focus

The IYPT provided a 'hook' not only to engage with schools, but also to re-position how chemistry is playing a role in sustainable development from the perspective of students. Future international 'hooks' will include the International Year of Basic Sciences for Sustainable Development (IYBSSD) in 2022.

Positioning chemistry outreach in curriculum contexts

Schools primarily chose which student year levels to involve based on their syllabus for that year level, in order promote the relevance of studying chemistry at a secondary and post-secondary level. Teachers also benefitted from understanding how to 'continue the conversation' in their own classrooms after the outreach event.

BARRIERS

Constraints of ethically conducted research evaluation

Conducting research in line with government research guidelines for informed consent constricted how potential involvement in events was promoted to schools. First, we initially intended to recruit students identifying as indigenous, but NHMRC ethical guidelines designated this recruitment approach as 'high risk', and so it could not be pursued within the short time frame of the project. Second, interested schools may have chosen not to be involved because of the extra steps involved in facilitating informed consent from parents and students.

One day outreach events

For the impact of outreach to be authentic and sustainable, long-term engagement has the greatest potential to improve student participation in STEM and to change attitudes towards meaningful action in sustainable development. Future directions of our chemistry outreach is focussing on developing multiple 'touch points' with schools, teachers and students, be it face-to-face or online, over a longer period of time.

FUTURE DIRECTIONS

Finishing our analysis of the rich, multi-stakeholder data collected will be invaluable to evaluate the impact of our chemistry outreach events. Another set of chemistry experiments has already been designed. A collaboration with universities across NSW has also been established, to explore the possibility of expanding our approach to chemistry outreach.

We have presented initial findings from this research at national and international science and chemistry education conferences. We are confident that what has been established with this project in 2019-2020 will provide a perfect basis for new ventures in our interdisciplinary *Elements of Sustainable Chemistry* research team, to have a further impact in supporting schools to educate how chemistry can play a role in meeting sustainable development goals.

Photo (top): Chemistry demonstrations at Brauer College, Warrnambool

Photo (middle): University student mentoring of student leaders, Swan Hill College

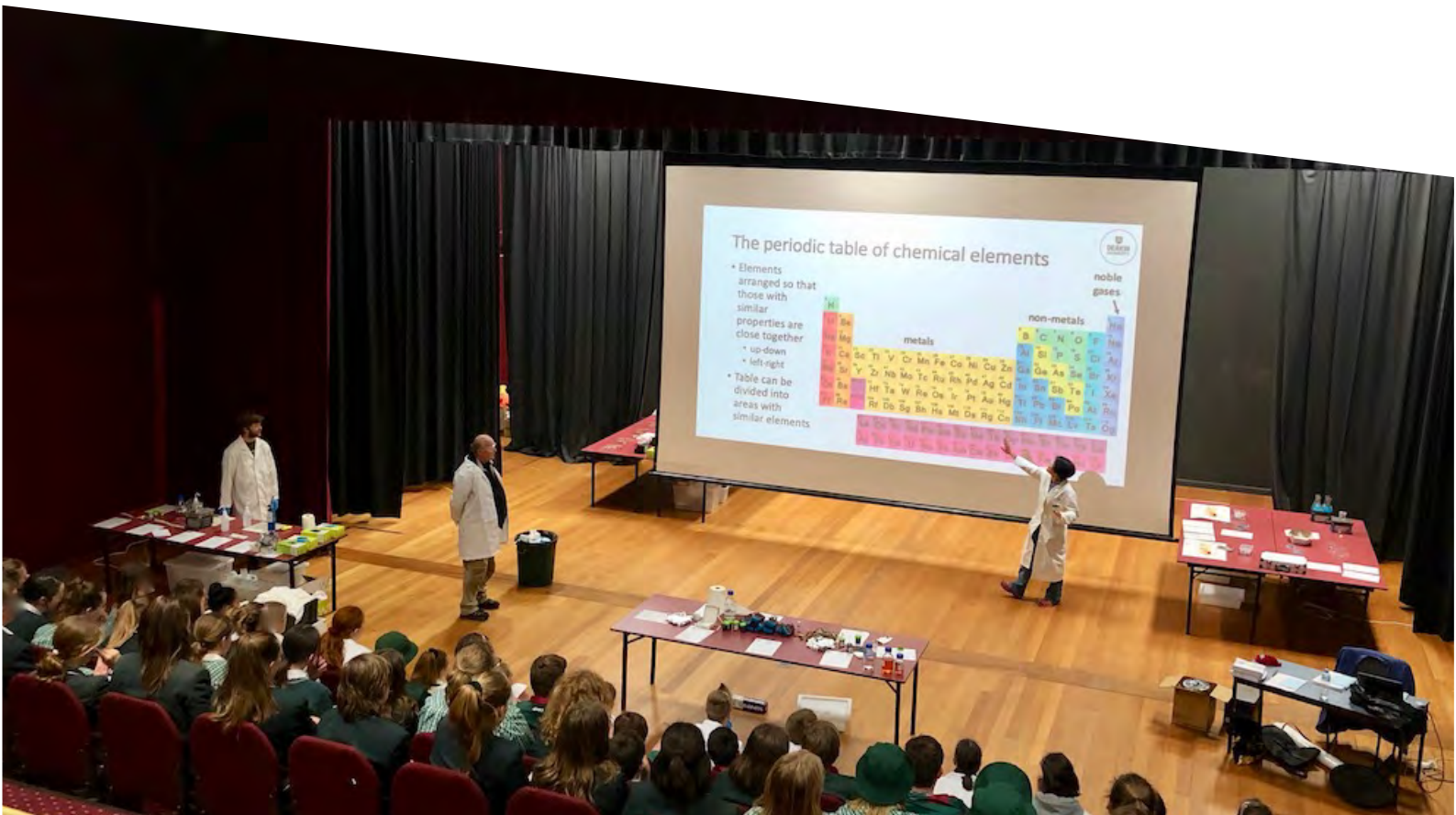
Photo (bottom): Students inquiring about elements in the Periodic Table 'briefcase', East Loddon P-12 College

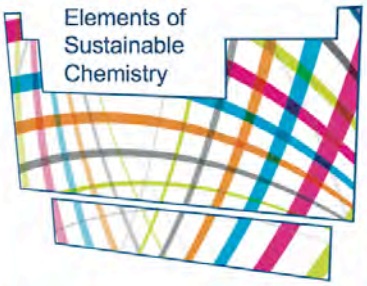
Photo (next page): Introduction seminar at Brauer College, Warrnambool

ACKNOWLEDGEMENTS

The project successes achieved in this project would not have been possible without the support of many others who contributed along the journey. We wish to immensely thank the following:

- The Australian National Commission for UNESCO, for their generous 'International Year of Periodic Table' grant. In particular, the previous Secretary-General, Sue Moore, who helped us align our project priorities after the grant was awarded.
- Deakin University's School of Life and Environmental Science, who financially supported the NISEP Director A/Prof Joanne Jamie's visit to Deakin University.
- Deakin University's Research for Educational Impact (REDI) for financially supporting Ms Jue Soo, who contributed as a research assistant to the research.
- Deakin University's Science and Society Network (SSN), for financially supporting the establishment of the *Elements of Sustainable Chemistry* research hub.
- Prof Stuart Batten (Monash University) for kindly lending his excellent 'Element briefcase' and inspiring our popular element sorting activity with his Element kits.
- Peter Johns at Butterpaper, for the design and construction of the project website.
- Prof Peter Mahaffy (King's College, Canada, IUPAC Task group chair on 'Systems Thinking in Chemistry Education' project) and A/Prof MaryKay Orgill (University of Nevada, USA) for advice on embedding systems thinking into our research approach.
- Our amazing University student volunteers, who played a vital role not just in the school visits, but also with the necessary work before and after each event at Deakin laboratories.
- The seven schools who took a chance and embraced this new approach to school outreach in Victoria.
- The teachers who made our event at each school possible, in particular Susanna Rizzo and Gabriele Smales (Bellarine), Vivienne Bonnell (Nhill), Anna Gage (Brauer), Rebecca Johns (East Loddon), Terri Gregotski and Trish Hayes (Wodonga), Lee Tompsett (Swan Hill) and finally Libby Dean, Phillip Rigby and Esther Dudley (Bright).
- And of course to the student leaders and students who took part at each of the school events. We hope that you enjoyed this experience!





United Nations
Educational, Scientific and
Cultural Organization

**Australian
National Commission**
for UNESCO

The Periodic Table of Sustainable Elements has received grant funding from the Commonwealth Government through the Australian National Commission for UNESCO