OUR GEOTHERMAL AREA: A JOINT GNS / TAUPŌ-NUI-A-TIA COLLEGE INTEGRATED SCIENCE EDUCATION INITIATIVE

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ABSTRACT

Science and technology are crucial for New Zealand's continued economic growth and social and environmental wellbeing, but require a sustainable, highly-skilled workforce and an informed, engaged public. Domestically, science and technology graduate numbers are increasing, but as global demand grows faster, a national skills shortage is predicted. There is also a noticeable decline in the uptake of, and performance in, science subjects at the senior high-school level.

GNS science and Taupō-nui-a-Tia College are developing a long-term geothermal monitoring initiative designed to increase student engagement and performance in science throughout the course of their high school education. Using an integrated approach that combines subjects traditionally taught independently, students will monitor public-owned thermal features in the Taupō area and disseminate their findings to the local community via a public-access database and website. The premise is to move education from the classroom to 'real world' environments, enabling students to realise the relevance of their learning experience. The project provides opportunities for participants to build partnerships with scientists, stakeholders and the local community, and to discover science career pathways.

To test the project's viability, a pilot scheme commenced earlier this year (with some funding assistance from MBIE's 'A Nation of Curious Minds' fund) with one class of Year 10 students monitoring one thermal area. Participants measure soil temperature and fumarole activity at dedicated sites every two to three weeks and are analysing their data during integrated science and maths lessons. Students will have the opportunity to present their results to GNS staff, local council and other community members.

The major challenge for the future is in the logistics of expanding the project to include all of the Taupō-nui-a-Tia College students, and involve other subjects in the school curriculum. Our ultimate goal is to develop a science- and technology-based, integrated model of teaching using a local environment and community focus that can be commuted to other New Zealand high schools.

1. INTRODUCTION

In recent years there has been a relatively low uptake of science-related subjects by senior high school students at Taupō-nui-a-Tia College (Taupō College), and subsequently by those from the College advancing to tertiary education. Anecdotally, Taupō College students have been disinclined to pursue senior high school science because the subject is deemed "too hard".

This is not just a 'local' phenomenon. According to New Zealand Immigration and government 'employment outlook' reports, there is currently a significant national shortage of suitably qualified and skilled scientists, engineers, technologists, and ICT professionals (Ministry of Business Innovation and Employment [MBIE], 2014). The number of domestic graduates in science, technology, engineering and mathematics (STEM) subjects is slowly increasing, but global demand for STEM graduates is growing faster. International estimates suggest that up to 75% of high-growth jobs require skills and competencies in STEM subjects (MBIE, 2014). It is estimated that less than half of the domestic students completing bachelor or higher degrees in STEM subjects continue on to work in their field of study, and that many of those who do pursue STEM-related careers are lost to New Zealand by the more competitive international job market (MBIE, 2014). There is also a noticeable decline in the proportion of senior high school students (Years 11 to 13) enrolling in science-related subjects in recent years. In addition, of those students continuing with science subjects in their final high school years, academic performance is significantly declining (MBIE, 2014).

Science and technology are crucial for New Zealand's continued economic growth and improved social and environmental wellbeing. Many of the challenges faced in today's society depend on science and technology for a solution (Gluckman, 2010). Thus a highly-skilled STEM workforce is essential to New Zealand's future.

Science is embedded in many of the decisions made by society through policy makers, business, communities and individuals (MBIE, 2014). Thus, science and technology literacy is not just for those who see their careers in this arena but is an essential component of core knowledge that every member of our society requires (Gluckman, 2010).

GNS Science (GNS) were approached by Taupō College to develop a 'real' science project for their students—one that not only had relevance to the students and to their local community, but also had tangible value to the science community.

The unique, diverse geothermal and volcanic environment around the Taupō district is an ideal natural classroom. Numerous active surface thermal features occur throughout the Taupō environs, many on publically-owned land, but regular monitoring of these is not often undertaken, due to financial and time constraints. These areas are, however, an important recreational and cultural resource for local communities.

Following consultation with Taupō College teachers, GNS devised a geothermal-themed, integrated science project entitled 'Our Geothermal Area', that allows students to tap into this free natural resource, in partnership with scientists from GNS. The project involves high school students ‘adopting’ and regularly monitoring various public-access thermal areas around the Taupō locale, and disseminating their knowledge within the local community. A pilot project involving one class of Taupo College students was commenced in March 2016 to determine the viability of this initiative.

This short paper reports on the ‘Our Geothermal Area’ project, including aims, principles and goals, project design and activities, and progress of the pilot project to date. A complimentary paper (Sanders et al., 2016, these proceedings) reports on some of the monitoring data collected during the first five months of the pilot project.

2. THE ‘OUR GEOTHERMAL AREA’ PROJECT

2.1 Project aims

The main aim of the project is to encourage more Taupō-based students to continue with STEM-related subjects throughout their senior high school education. The expected outcome of this is an increased uptake of STEM subjects at tertiary level by Taupō students and subsequently an increase in STEM-qualified graduates.

The project also aims to enhance local community engagement in science, by creating opportunities for high school students to interact with local community about the ‘Our Geothermal Area’ project through various media.

2.2. Project principles

The premise of the ‘Our Geothermal Area’ project is to take science-and-technology-related education out of the classroom and into the local environment. This ‘backyard science’ approach is designed to enable students to realise the relevance of science in a real-world context.

Taupō College staff envisaged a project that took an integrated approach to learning, in that it could encompass learning opportunities for other subjects traditionally taught independently of each other. The project design integrates multiple school-taught subjects, e.g., English, mathematics, computer science, to provide a greater contextual basis to these subjects for the students. For the pilot project, mathematics and science lesson are integrated.

The monitoring aspect of the project is designed for students to learn: safe working in geothermal areas; technical field work skills (e.g., data collection and recording, equipment use); consistent collection of scientific data; statistical analyses, and presentation of numerical and other scientific data.

The project objectives, activities and outputs are intended to have tangible value to the Taupō community, GNS Science and other stakeholders. The project will enable students to engage with and build partnerships within the local community, and will provide opportunities for students to discover science career pathways that they may otherwise have been unaware.

By entrusting school students to monitor our local geothermal features, as part of a multi-disciplinary curriculum, invaluable opportunities arise for students, scientists and the community to learn more about these unique natural environments (relevant on a local and national level), including natural “change” in such systems, their response to geothermal resource development, and on-going preservation.

The project is supported by geothermal expertise from GNS scientists, including assessment (scientific and hazard) of suitable thermal areas for students to monitor, background knowledge and support for school teachers, assisting with developing field health and safety protocols, and scientific support at each student monitoring site visit. GNS will also build and host the project database (a long-term project), and will remain actively involved in developing the long-term project.

3. THE PILOT PROJECT

To test the feasibility of a long-term, fully-integrated geothermal monitoring project, a pilot project was initiated in March 2016, in which twenty-nine Year 10 (ages 14 – 15) high school students undertook regular scientific monitoring of one public-access active thermal area in Taupō for the duration of the 2016 school year.

The Crown Park thermal area (Figure 1) was chosen for the pilot project because of its proximity to Taupō College, manageable size and suitability of thermal features for monitoring and relatively low hazards compared to some other active areas in Taupō. It is located in a public park on the eastern fringes of Taupō township, near the south-western resistivity boundary of the Tauhara geothermal field (as defined by Risk et al., 1984; Figure 1). The active thermal area is characterised by multiple, intermittently active fumaroles and hydrothermally altered soils.

Figure 1: Location of Crown Park thermal area (denoted by red square) relative to the Wairakei-Tauhara geothermal field (outlined by the resistivity boundary (red shading) as defined by Risk et al., 1984).

The project also included some preliminary activities, prior to commencing monitoring at Crown Park, to serve as an introduction to the project and provide some underpinning geological principles.

3.1 Preliminary pilot project activities

The pilot project was designed to enable the participating students to undertake a Geology component as part of their usual curriculum. To compliment this, an introductory presentation on geothermal systems in New Zealand was given to the students by renowned GNS geothermal scientist, Dr G. Bignall.

Subsequent to this presentation, students participated in a field-trip to Wai-o-Tapu Thermal Wonderland, accompanied by two GNS scientists, to visualise the geological concepts and geothermal processes they had been introduced to (Figure 2). During this trip the students completed worksheets (jointly devised by Taupo College teachers and

GNS scientists) in which they answered questions relating to the features they observed. These formed part of their internal assessment for the NZQA Geology module.

Prior to commencing scientific monitoring activities, project participants were introduced to the Crown Park thermal area during a half-day field trip to the site, also accompanied by GNS geothermal scientists. During this visit the students explored the local geology, thermal features, hydrothermal alteration and vegetation at the site. In addition, to give the students a sense of ownership of the Crown Park thermal area, the students undertook a clean-up of dumped waste at the site during this visit.

Figure 2: GNS geothermal scientist Mark Simpson (in orange high-vis vest) explains some of the features of the Champagne Pool (Wai-o-Tapu Thermal Wonderland) to a group of 'Our Geothermal Area' pilot project students from Taupō College. Photograph courtesy of L. Brown, Taupō College.

3.2 Crown Park thermal area monitoring

GNS scientists designed the pilot project to maximise the scientific monitoring skills developed by the students, using a range of monitoring equipment, and to create a comprehensive and robust dataset. To this end, the project students were divided into three groups (nine or ten students per group). Each group takes turns to visit the thermal area to collect monitoring data from one of three transect lines plotted in the active thermal area (Figure 3) and fumaroles. During monitoring visits, each of these groups was further subdivided into three teams, with each team taking part in a different monitoring activity. At subsequent monitoring visits, the teams rotated through each of the monitoring activities, thus learning new skills at each visit.

Monitoring visits initially took place fortnightly, with the exception of school holidays, to allow students to become familiar with the monitoring techniques. Therefore, depending on school holiday dates, there were six to eight weeks between data collection at each of the transect lines between March and July. Since July, the frequency of monitoring visits has been reduced to every three to four weeks, to accommodate other aspects of the school curriculum. Monitoring visits occur during a two-hour science class slot in the class timetable. Two GNS staff (geothermal scientists and / or experienced geothermal field technicians) accompany each monitoring visit to mentor the students, along with one Taupō College teacher (science or mathematics).

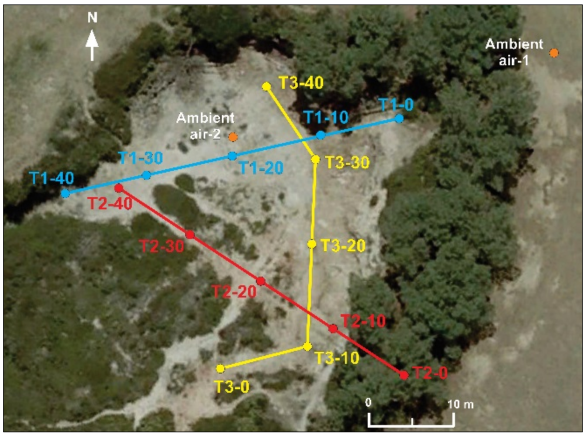

Figure 3: Location of three transect lines and soil temperature measuring locations at Crown Park thermal area. Blue line = Transect 1; Red line = Transect 2; Yellow line = Transect 3. Ambient air measuring locations denoted by orange markers.

At the start of each monitoring visit, the students participate in a health and safety briefing, led by GNS personnel, and students do not enter the active thermal area / undertake monitoring activities without wearing appropriate protective equipment.

Monitoring activities undertaken at each monitoring visit are as follows:

- *1 m depth soil temperature profiles*: one team of students measures soil temperature at 5, 10, 15, 20, 25, 50 and 100 cm depths, at 10 m intervals along the designated transect line (Figure 3), using a 1 m length K-type thermocouple temperature probe and Yokogawa TX10 digital thermometer (Figure 4A). Start and end points of each transect line were plotted using GPS coordinates (recorded by the students during initial visits to each transect line) and these, along with photographic records ensure the transect lines are positioned correctly at each monitoring visit.
- *20 cm depth soil temperature*: the second team measures a single soil temperature at 20 cm depth (Figure 4B) at 1 m intervals along the same transect line as the first team, using 20 cm length K-type thermocouple temperature probe and Yokogawa TX10 digital thermometer.
- *Ground cover description*: both 'soil temperature' teams also record the percentage of bare ground versus vegetation cover, using a 1 m square quadrat (Figure 4C), at each of their respective temperature measuring locations. They also record vegetation species and average height (if present), colour of the soil, and the degree of ground hardness. Photographs of the ground cover at each temperature measuring location have also been collected since June.
- *Fumarole descriptions:* during the initial three monitoring visits, the third team of students recorded comprehensive descriptions of each fumarole identified at the site. These included location of the fumarole (including GPS coordinates of some fumaroles for reference), distance and direction from nearest other fumarole, collapse crater dimensions (where applicable), location of vent within crater if visible (where applicable) and a photograph of the crater / vent.

- *Fumarole monitoring*: undertaken at every monitoring visit, the third team documents visible and audible steam activity, measures fumarole steam temperature (using a 1 m length K-type thermocouple temperature probe and Yokogawa TX10 digital thermometer), and gas composition (using a Dräger X-am 5600 handheld gas detector; Figure 4D) of active fumaroles, and records 20 cm deep soil temperatures, measured 20 cm horizontal distance from the fumarole vent / collapse crater edge, at all fumarole sites (active and inactive). A photograph of the crater / vent is also taken at each visit.

  Attempts were initially made to quantify fumarole steam activity by measuring steam velocity using a handheld anemometer (attached to a long wooden pole). Due to the diffuse and sometimes sporadic nature of the steam plumes, this method proved unsuccessful. At present, students note the height above the vent at which the steam from active fumaroles dissipates and record a short video documenting the steam activity.
- *Ambient conditions*: ambient air and soil conditions are recorded at each monitoring visit. Ambient air temperature, gas concentration and wind speed is measured by one team of students at the lowest elevation point of the active area (Ambient air-2), and at higher elevation out with the active area (Ambient air-1; Figure 3).

  Ambient soil temperature (at 20, 50 and 100 cm depth) is measured by the GNS staff accompanying the monitoring visit at a non-geothermal site located approximately 3.5 km north-west of Crown Park, by the Lake Taupō look-out at the junction of Huka Falls Road and State Highway 1.
- *Weather data*: weather data (including daily rainfall and air temperature) recorded at the Taupō Airport weather station located 5 km east of Crown Park, is downloaded (by GNS staff) from the NIWA National Climate Database (https://cliflo.niwa.co.nz/) after each monitoring visit for use in subsequent data analyses.

During the first few Crown Park monitoring visits, students recorded their data on paper forms, specifically developed by GNS for the project. This data was subsequently transcribed into an Excel spreadsheet. However, a major goal of the project is for the monitoring data to be available to the public. To facilitate this, GNS developed a custom-designed, digital data collection form using the Fulcrum Mobile Form Builder and Data Collection platform. Students now digitally record monitoring data on iPads (purchased by the school with funding from MBIE) which store and upload the data to a database hosted by Fulcrum. GNS is currently developing a project website that will provide a link to this data to make it available to the public.

3.3 Crown Park monitoring data analyses

GNS were tasked to design a project that enabled students to realise the relevance of science in the real world. We hope to achieve this by the students learning to process, analyse and interpret the data they collect. Mathematics lessons have been integrated into this project, in which the students learn basic data analyses techniques. These include exploring ways to plot and visualise the various data, looking for trends in the data, and comparison of different datasets. Interpretation of their results, and how these might affect the local community, will be derived through discussion in both mathematics and science classes, as well as with the GNS scientists accompanying the monitoring visits.

Figure 4: Taupo College students undertaking various geothermal monitoring activities at Crown Park thermal area. A. Measuring 1 m depth soil temperature profiles on a transect line; B. Using a screwdriver and mallet to create a hole for measuring 20 cm depth soil temperature on a transect line; C. Use of 1 m square quadrat to record ground cover. D. Measuring gas concentration at an active fumarole.

3.4 Presentation of results

A major goal of the project is for the participating students to engage their local community in the science they are involved in. The raw data collected by the students will be available on the project website currently being developed by GNS. A project Facebook page has also recently been set up for the students to share photographs and stories about their experiences during the project. Additionally, two articles have appeared in the local newspaper to date about the project with at least one more article planned before the end of the project.

Once the last monitoring visit has taken place (November 2016), students will create a visual display for the main foyer of Taupō College, detailing their monitoring activities, data collected, analyses and interpretation. This will be in place for approximately the last three weeks of the school year, enabling other Taupō College students and teachers, and parents and other visitors to the school to learn more about the project.

At the end of the pilot project, the students will visit the GNS Wairakei Research Centre to present their project to GNS scientists, and other invited guests from local council, local Iwi, teachers from other high schools and the students' parents. As part of this presentation, GNS scientists will share the results of their own analyses of the Crown Park data. In this way, the students will see the impact of their science activities on 'real' scientists.

4. MEASURING PROJECT SUCCESS

We believe that the pilot project can be considered a success if even one of the students is inspired by this new learning experience, remains engaged in the project throughout its duration, and is motivated to continue to learn science in subsequent school years.

At the start of the pilot project (in February 2016), and at various stages throughout the project to date, students have completed a short survey to determine the impact the project has on their interest level of motivation to learn science. An end of pilot project survey is also planned.

At the time of writing, we have received very positive feedback from the students and teachers involved in the project, both anecdotally and through student surveys. At least two students have expressed a desire to study geothermal science at tertiary level, and project students report positive learning experiences from the monitoring activities. Both of the Taupō college teachers (science and mathematics) involved in the project have also noted an increased level of engagement by the project students in their classes.

At the end of the pilot project, success will also be measured by:

- An improvement in the overall attendance record of the pilot project students.
- A high percentage of the pilot project students achieve merit excellence levels in the NZQA Level 1 standards.
- Improved end of year exam and other internal assessment grades of pilot project students in science and maths (and in other subjects).
- Monitoring pilot project student satisfaction with / attitudes about the project through student surveys.
- A high percentage of pilot project students plan to continue with science education, and plan remain involved in the longer-term project throughout the remainder of high school.
- Other students and teachers at Taupō College, and other local high schools show interest in becoming involved in the on-going project in subsequent years.

In the long-term, the continuing success of the on-going project will be measured by:

- An increase in the number of students from schools participating in the project that continue in science-related subjects during their senior high school years.
- An increase in the number of students who pursue science-related studies at tertiary education level.
- An increase in the number of students who take up the Gateway work-experience opportunities at science-related workplaces (e.g., GNS).
- Local communities are better informed about their local geothermal environment and are inspired to keep these areas waste-free.
- Tangible evidence that students are more fully involved in their local community and environment, e.g., actively writing to the newspaper about local science and environment issues, mentoring younger students as they participate in the on-going project, volunteering for or initiating community science or environmental projects.

And the ultimate success: every school in New Zealand is engaged in 'real-world' science projects within, and relevant to, their local community!

5. THE NEXT STEPS

Our medium-term vision is to include all students from Taupō College and other Taupō-based high schools, throughout their high school education, in an on-going 'Our Geothermal Area' project in which most (or all) of the public-access thermal areas in the Taupō area are regularly monitored. The idea is that during each new school year students will undertake regular scientific monitoring at a different location, thereby learning new monitoring and, at senior levels, sampling skills. Senior students will also have opportunities to undertake more specialised projects, depending on their areas of interest, e.g., chemical analyses of geothermal water samples, shallow hydrogeological modelling, or participating in surface heat flow studies. Additionally, because the project integrates multiple subjects, students that choose not to continue in science at senior levels can still be involved in the project through other STEM subjects, e.g., IT students could develop 3D models of the thermal areas being monitored using UAV technology, or engineering / design students could develop tools and techniques for sampling hard-to-reach or hazardous thermal features.

However, the major challenge in realising these goals is integrating the project design into the current school curriculum, and into the existing 'class timetable' system. At present, the way the curriculum is delivered in most New Zealand high schools (including Taupō College) precludes further expansion of the 'Our Geothermal Area' project, both in terms of including all students in a single high-school year, or of extending the project to include levels higher than Years 9 and 10. One of the main difficulties lies in a 'stream' system, where students are placed in specific classes (streams) according to their ability / level of understanding in each subject; thus, students may be in one 'stream' for science but in a different 'stream' for mathematics. Integrating students from different streams, is usually difficult because of timetable clashes. Additionally, curriculum content is generally taught as separate modules over a single school term, thus a year-long monitoring project does not easily fit into this model.

Taupō College is currently undergoing a major review of their delivery of the national curriculum and of their existing timetabling system, in a move towards a more integrated and contextual-based approach to learning, which will address some of the challenges outlined.

In the meantime, next year (2017) we plan to expand the project to include two Year 10 classes from Taupō College, with a view to undertaking some of the preliminary project activities, e.g., the introductory geothermal systems presentation and Wai-o-Tapu Thermal Wonderland fieldtrip towards the end of this year (2016), while these students are still in Year 9. This would enable the monitoring aspect of the project to commence approximately a month earlier in 2017. We are also currently in discussions with teachers from Tauhara College, Taupō, with a view to commencing a pilot monitoring project with their students in 2017.

Ultimately, we plan to develop a science-and technology-based, multi-disciplinary model of teaching, with a local environment/community focus, that can be commuted to all New Zealand high schools, and potentially into intermediate and primary school level.

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