An evidence-based approach to secondary school science: Online citizen science and the science capabilities

Cathy Buntting, Azra Moeed, Dayle Anderson, and Richie Miller

https://doi.org/10.18296/cm.0059

[Abstract]

As part of a multiyear research project investigating the affordances of online citizen science (OCS) projects for enhancing school students' learning in relation to science and digital technology, teacher–researchers have designed and implemented classroom interventions incorporating one or more OCS projects. The project is situated in New Zealand, and each intervention has embedded an OCS project within a wider unit of learning focusing on one or more "science capabilities" (Ministry of Education, n.d.). This article presents one of the case studies generated in the wider project. It is of a Year 9 class that engaged with the OCS project Planet Four as part of a wider inquiry unit emphasising the science capability Use evidence: "Can humans live on Mars?" The findings demonstrate that a deliberate focus on using evidence throughout the unit gave students multiple opportunities to practise and develop this science capability within the engaging context of space travel.

[Abstract ends]

Introduction

This article reports on a single interpretive case study developed as part of a multiyear research project funded by New Zealand's Ministry of Education's Teaching and Learning Research Initiative (TLRI): On2Science—Multiple affordances for learning through participation in online citizen science (OCS). The affordance of embedding OCS projects in school science programmes is a nascent field of research, with a recent systematic review of learning through OCS projects highlighting the need for studies investigating the impacts of engaging with OCS projects in formal education (Aristeidou & Herodotou, 2020). Our larger project responds to this call for studies investigating the ways in which OCS projects can support school learning. Here, we present an interpretive case study of a Year 9 class (13–14-year-olds) who engaged with the OCS project Planet Four as part of a wider inquiry unit emphasising the science capability Use evidence: “Can humans live on Mars?” The findings demonstrate that, through careful and deliberate planning, the teacher was able to maintain a focus on the science capability Use evidence while also addressing curricular content goals. First, we introduce the science capabilities and how they connect with *The New Zealand Curriculum (NZC)* (Ministry of Education, 2007). We then review the relevant literature relating to OCS projects and school science before outlining the development of the case study presented here.

Science capabilities and *The New Zealand Curriculum*

NZC (Ministry of Education, 2007) positions science as one of eight key learning areas. Within this learning area, there is a focus on how science works: the Nature of Science (NOS) is the overarching and compulsory strand through which students learn that “science is a way of investigating, understanding, and explaining our natural, physical world and the wider universe” (p. 28). The aim of the learning area is for students to “explore how both the natural physical world and science itself work *so that* they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role” (p. 17, emphasis added). In other words, the curriculum focuses on scientific literacy: “the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen” (OECD, 2019, p. 100).

To support students’ development of a functional rather than declarative knowledge of NOS (Allchin, 2017), and to help teachers to bring the different parts of *NZC* together in relation to science, the Ministry of Education (n.d.) identified five science capabilities: Gather and interpret data; Use evidence; Critique evidence; Interpret representations; and—using the previous capabilities in combination—Engage with science. These were linked to *NZC*’s NOS substrands (Hipkins & Bull, 2015), as shown in Table 1. To support teachers to engage with the science capabilities, the Ministry of Education published a number of examples alongside the capabilities, suggesting how each capability might be developed using existing resources. Very broad descriptions are also provided of how tasks might differ at the different curriculum levels. For example, at the lower levels, tasks may be less ambiguous, be set in familiar contexts, and use everyday ideas or simple science ideas. At higher levels, the tasks are likely to be more ambiguous, set in a wider range of familiar and unfamiliar contexts, and draw on students' prior knowledge of relevant science concepts.

Table 1. The relationship between the Nature of Science substrands and the science capabilities

Nature of Science substrand	**Science capability**
"Understanding about science"	Gather and interpret data Use evidence Critique evidence
"Investigating in science"	
"Communicating in science"	Interpret representations
"Participating and contributing"	Engage with science

These generic descriptions for progression illustrate a key challenge with developing indicators of learning progress for the science capabilities; that is, they are holistic in nature. However, emerging evidence is providing further clarity about what progress in learning might look like in relation to the science capabilities. For example, Bull (2015) reported on a small research study in which students from Years 1–10 completed some of the assessment tasks published as part of the original science capabilities resources. She suggested using overall teacher judgements of how closely students resemble an "ideal" profile, with assessment tasks focusing on identifying next learning steps. Three "ideal" profiles were provided with the intention of giving teachers "ideas about how to further extend their students" while "maintaining the holistic nature of the capabilities" (p. 11). Subsequently, the 2017 National Monitoring Study of Student Achievement (NMSSA) focused on science and was substantially based on the science capabilities. The data, from over 2,000 students in Year 4 and Year 8, were analysed for evidence of progress in the five science capabilities. The resultant "rainbow diagram" (Ministry of Education, 2019, pp. 6–7) provided some draft indicators of progress for Level 2, above Level 2, Level 4, and above Level 4. (*NZC* has eight curriculum levels, where Level 2 typically relates to learning in Years 3, 4, and 5—or 8–10-year-olds, and Level 4 typically relates to learning in Years 7, 8, and 9—or 12–14-year-olds.)

According to the NMSSA data, progress in capability development is generally associated with increased use of logic and more nuanced reasoning and application of a greater range of skills as students draw on their growing scientific knowledge when considering less familiar and/or more complex contexts and ideas. However, gaps in the NMSSA data mean that some of the levels are not populated for each of the science capabilities. In other words, the fact that there are no indicators for Critique evidence, Interpret representations, and Engage in science at

Level 2 does NOT mean that students at this level are not able to Critique evidence and so forth. Rather, the NMSSA data could not give insights into what these capabilities might look like at this level.

Additional work is therefore needed to provide empirical evidence of indicators of progress in science capability development—and how teachers can support ongoing learning. Previously, we have reported on a case study with Years 5 and 6 students (10–11-year-olds) that, with expert teaching, students are able to demonstrate an ability to critique evidence "well above that of their 'expected' level" (Anderson et al., 2020). Here, we report on a Year 9 class (14-year-olds) where the focus was on developing the science capability to Use evidence in the context of an astronomical unit designed around the inquiry question: "Can humans live on Mars?" The unit was designed as part of the wider TLRI project described earlier, and the OCS project used as an anchor for the unit was Planet Four. The research question this case study responds to is: What are the impacts of designing a junior secondary school science programme that focuses on the nature of science by embedding an OCS project and emphasises the use of evidence throughout the unit?

Online citizen science and school science

"Citizen science" projects are typically defined as projects where non-scientist, "lay" participants contribute in some way to active science investigations, whether through designing the investigation, collecting the data, processing the data, analysing and interpreting the data, and/or sharing the findings (Eitzel et al., 2017). In OCS projects, some or all of the lay participants' contributions occur via the internet—giving anyone with a digital device and internet connection access to authentic science research projects. With the growth in citizen science and OCS projects internationally, interest has turned to the impacts of engaging with these projects as part of school teaching and learning programmes (Kloetzer et al., 2013).

While there is growing literature reporting on the impacts of engaging in local citizen science projects, fewer published studies report on the impacts on learning when school students engage in OCS projects. As we have previously highlighted, these studies also "tend to focus primarily on teacher practice, highlighting the scaffolding that is needed for learning opportunities to be maximised" (Anderson et al., 2020, p. 41). Fewer studies specifically explore the gains in students' conceptual, procedural, and/or epistemological learning when they engage with OCS projects. For example, Chen et al. (2012) describe a study of Year 4 (8–9-year-old) students in New Zealand who engaged with a national OCS project tagging and logging the location of monarch butterflies as part of a wider butterfly unit. Through the unit, which included engaging with the OCS, the students learnt about butterfly life cycles, as well as developing topic-specific scientific language, asking scientific questions, making observations, and suggesting explanations for patterns in data. Similarly, 9–14-year-olds in the US, Mexico, India, and Kenya who uploaded photographic data to the OCS project *eMammal* were shown to be learning about their local environment, connecting with nature, posing scientific questions, and sharing their findings with the wider community (Schuttler et al., 2019).

Aristeidou and Herodotou's (2020) systematic review of studies investigating learning impacts of engaging with OCS projects identified only 10 empirical studies across a number of research databases, all of the studies involving adults engaging with OCS projects in informal education settings. Across these studies, there was evidence that learning arising from engaging with OCS projects can relate to topic-specific knowledge, science knowledge, nature of science, and generic knowledge (e.g., digital literacy). These findings are of value, they argue, in order to inform OCS project design. For example, insights can be gained into the scaffolding mechanisms that may facilitate learning outcomes for participants. In formal education, teachers play a key role in scaffolding the learning experiences of students as they engage in OCS projects, enhancing learning opportunities (Pierson et al., 2020). This was particularly evident in the ways in which teacher Melissa scaffolded Years 5/6 students' engagement with *Globe at Night*, and the resultant opportunities for students to develop the science capability Critique evidence (Anderson et al., 2020). Here, we report on ways in which teacher Richie (the fourth author) provided multiple scaffolds for Year 9 students to develop the science capability Use evidence. Our purpose is twofold: to contribute to evidence of students' science capability development in New Zealand, and to contribute to international understandings of the ways in which OCS projects can be used to anchor school teaching and learning programmes in order to enhance students' learning opportunities in science.

Methodology

This study was situated within an interpretive paradigm, where the data are framed by the participants' and researchers' experiences and where the findings are socially constructed (Ling & Ling, 2017). Further, the study is presented as a case study, where case studies are described by Bassey (1999) as "enquiries into educational programmes, systems, projects or events to determine their worthwhileness, as judged by analysis by researchers, and to convey this to interested audiences" (p. 58). Accordingly, data were collected to "(a) explore significant features of the case, (b) create plausible interpretations of what is found, (c) construct a worthwhile story, and (d) convey convincingly to an audience the argument or story" (p. 58).

The case is of an 18-lesson Year 9 science unit 2020 based around the inquiry question, "Can humans live on Mars?" The unit was planned and taught by teacher Richie and the case includes the experiences of Richie as teacher-researcher, and the experiences and learning as articulated by his class of 31 students in a coeducational state secondary school in New Zealand. Multiple types of data were collected, enabling a rich picture of the case to be presented. The data sources were negotiated in advance and included a written questionnaire completed by Richie before commencing the unit, Richie's planning documents, a written reflective journal kept by Richie, copies of student work, three classroom observations and recorded discussions with Richie after each observation, and two end-of-unit surveys completed by the students. The study was approved by Victoria University of Wellington's Human Ethics Committee. Informed consent for the study was obtained prior to data collection from the school principal, Richie, the students, and their caregivers.

Commented [SC1]: Is this in the correct place?

An inductive approach to data analysis meant that we looked for themes emerging from the data. Working closely as a research team enabled the co-construction of a shared understanding of the impacts of the teaching intervention (i.e., an astronomy unit Life on Mars), that focused on students having multiple opportunities to learn to use evidence, and that included engaging with the OCS project Planet Four. In practice, this meant that at least two of us considered each data set, enhancing the reliability of our interpretation. The findings were also iteratively discussed between ourselves and with the wider TLRI research team, including other teacher–researchers.

Findings

Life on Mars: A Year 9 astronomy unit

The science unit Life on Mars was implemented during 2020 over a period of 18 lessons. The inquiry question "Can humans live on Mars?" formed the basis for the unit, which had as an overarching learning objective for students to develop the science capability Use evidence. The unit addressed Level 4 curriculum learning outcomes associated with Understanding about Science, Investigating in Science, and Astronomical systems; that is:

- Appreciate that science is a way of explaining the world and that science knowledge changes over time
- Identify ways in which scientists work together and provide evidence to support their ideas
- Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations
- Use their growing science knowledge when considering issues of concern to them
- Investigate the components of the solar system, developing an appreciation of the distances between them
- Recognise that there are life processes common to all living things and that these occur in different ways (Ministry of Education, 2007).

Commented [SC2]: Add a page ref if this is a direct quote.

A range of different teaching and learning activities were used, including modelling distances in space, modelling and investigating geyser and crater formation on Mars, engaging with the OCS project Planet Four, and completing a daily "evidence journal" (see below).

Planet Four

Planet Four is a research project that invites citizen scientists to process photographic data of the surface of Mars. Specifically, citizen scientists are given images taken of the surface of the south polar region of Mars, "where dark seasonal fans and blotches appear during spring" (Zooniverse, n.d.). The shape and direction of the "fans" provide indications of wind direction and speed. Citizen scientists help to process multiple Mars years of photographic data by identifying and marking the blotches and fans. By tracking changes over time, planetary scientists hope to better understand weather conditions on Mars.

Richie chose Planet Four because it was a project that would "fit perfectly" with the Mars astronomy unit that formed part of the school's Year 9 science programme. There were several other features of the OCS that appealed:

1. Photographs of the surface of Mars often intrigue people/students as they can recognise both features that look familiar and others that look very different.
2. The project's simplicity—classifying landforms—means that the students don't get bogged down in technical tools or processes. It is a very visual relationship between the image and modelling how these landforms can be created in the classroom (e.g., geyser fans and craters). These provide an excellent discussion base for asking what conditions formed these (carbon dioxide sublimation) and how this affects our chances of survival on Mars as human visitors.

3. I’m hoping the students will really connect with the fact that they will be helping these scientists explain unanswered science questions.

(Richie, pre-intervention questionnaire)

For the students to engage with Planet Four, a range of scaffolding activities were needed. Importantly, these activities provided opportunities for students to plan and carry out scientific investigations during which they practised identifying and using scientific evidence.

Students were also able to have an online conversation with the lead scientist of the project via zoom.

A focus on using evidence

At the start of the unit, Richie introduced the focus on using evidence through a diagnostic brainstorm to find out what students’ thought evidence was. Students individually entered their responses into a word cloud using the online programme AnswerGarden, resulting in the word cloud presented in Figure 1 (the font size is indicative of the number of responses). As can be seen, the most common response is related to the notion of proof, verification, backing something up, the idea that evidence is related to fact, examples of sources of evidence (e.g., data, research, footprints, photos, videos, samples), and some references to science. This word cloud became a useful focal point for further classroom discussion.

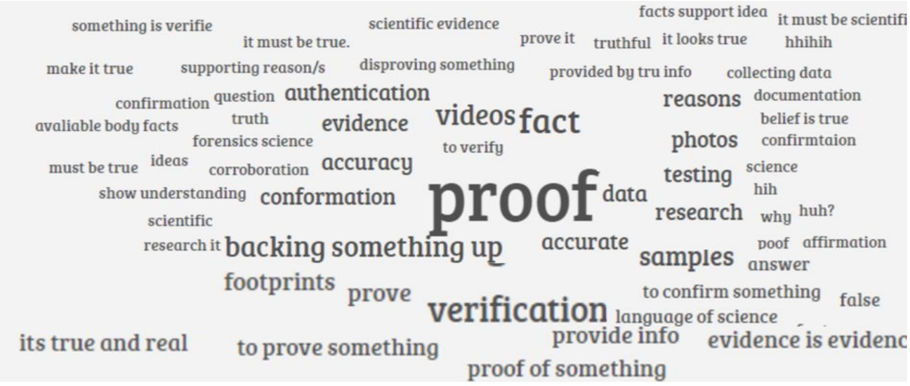

Figure 1. Word cloud showing responses to a diagnostic brainstorm: What is evidence? (Word Cloud generated by AnswerGarden)

Reflecting on the responses, Richie commented:

> [The] brainstorm on what is evidence brought up some insightful ideas. [There were] some words for justification like ‘back yourself up’. Photos as observational evidence was a common idea. (Richie, post-lesson reflective interview)

The use of evidence was an underpinning theme throughout the unit, with a specific focus on identifying and using evidence in many of the activities. For example, after the initial brainstorming activity about evidence, the class put 10ml of limewater ($Ca(OH)_{2(aq)}$) in a test tube and blew into it using a drinking straw. The carbon dioxide from human breath reacts with the limewater to form insoluble $CaCO_3$, which turns the solution milky. Richie explained that the change in the colour of the water provides evidence that there is carbon dioxide in their breath.

Further emphasising the focus on evidence, students were given time at the end of each lesson to make some notes in an online “evidence journal”. This journaling also helped students to explicitly connect each lesson’s learning with the unit’s inquiry focus: “Can humans live on Mars?” The journal had the same daily prompts, shown in Table 2.

Table 2. Response prompts in the daily evidence journal (Adapted from http://Ambitiousscienceteaching.Org/Get-Started/)

Can humans live on Mars?			
Activity	What we observed	How does this add to my theory? What is your evidence? *“This suggests it is/is not possible to live on Mars because …”*	Questions I still have *This can be anything related to living on Mars*

Hands-on learning

As part of the focus on evidence, the unit was characterised by a series of hands-on, practical activities, including making a scale model of space. Hands-on investigations were also critical scaffolds that helped students to understand how the blotches and fans visible in the Planet Four photographs had formed. Both features are thought to arise from the sublimation of carbon dioxide under the surface, the carbon dioxide erupting as a gaseous geyser. The evidence of this eruption becomes visible as “blotches” in the absence of wind, and “fans” when wind blows the eruption cloud, the direction of the fan correlating with the direction of the wind. To model this, Richie used a mixture of baking soda and vinegar to create a geyser, and a hairdryer to show the impact of a wind on the geyser spray. Students were asked to observe how wind speed and direction affected the spray patterns that formed—linking directly to the “fan” shapes visible in the Planet Four photographs.

Classroom observations revealed that students used observational evidence to make informed inferences. For example:

> The size of the fans formed by the geysers is dependent on wind direction and speed.

Meeting a Planet Four scientist

To support students’ understanding of Planet Four as an active science research project, Richie secured an online meeting with one of the lead scientists of Planet Four during class time. This conversation, lasting for nearly an hour, emphasised the “real-world” nature of the OCS project and the value of the contributions by citizen scientists. It became evident through the conversation that there are still a large number of unanswered questions about Mars that are being investigated by scientists:

> Student 1: What is the biggest geyser on Mars?
>
> Scientist: We don’t know.
>
> Student 2: Are the gases that come out of geysers on Mars dangerous to humans?
>
> Scientist: The geysers are solid CO_2 changing to gas. They’re not good for breathing in.
>
> Student 3: Is there any way to tell how loud the geysers are?
>
> Scientist: No, the atmosphere is very thin.
>
> (Observation notes)

Student learning

Evidence of topic-specific learning

There was substantial evidence throughout the unit of students’ topic-specific learning (for example, about the atmosphere and conditions on Mars). This evidence included comments made in classroom discussions and responses in students’ evidence journals. In addition, the end-of-unit online questionnaire asked students: “What is one thing you learned when using Planet 4? It could be an idea or a skill”. Twenty-eight students were in class that day to respond to the questionnaire. Of these, 23 (82%) wrote specifically that they had learnt about geysers and/or landforms on Mars. Within this group, six (21%) specifically stated that they had learnt to identify these landforms, and three (11%) linked this identification with the scientific inference that these shapes were indicators of wind speed and direction (e.g., “I learned to tell if the geysers were blotches or fans because of the wind”). At least three students (11%) had been impacted by the fact that so much is still not known about the surface of Mars (e.g., "I learned about geysers and how we don't know much about them").

A separate online reflection questionnaire, completed by all the students, asked students to respond to the prompt: "In this term I have learned …" Again, references to the landforms on Mars was the most common response (19 of 31 students, or 61%)—suggesting that this really had been an aspect that "stood out" through the unit. Students also referred to learning about differences between the atmospheres on Earth and Mars (32%), thinking about whether humans can live on Mars (32%), the scale of space (29%), and components of space suits (26%). One student commented more generally on their engagement through the unit:

> I wasn't really interested in space but this has changed my mind.

Evidence that students were using evidence

At the end of the second lesson, Richie wrote about the focus on using evidence in his reflective journal:

> Students starting to latch on to the 'how do you know?' mantra. When I ask questions such as 'What would you say if I said, *Larina is the best basketball player in the class?*' they shout back … 'How do you know?' Brings up good ideas like—we can measure—count the number of hoops in a minute.

This student's response in the classroom discussion [reading about Mars from a NASA webpage: mars.nasa.gov/all-about-mars/facts/] is indicative of the ways in which students learnt to explicitly refer to evidence in classroom conversations:

> The average temperature on Mars is around -81 degrees, but in the summer it can go up to 70 degrees Celsius near the equator. Based on this evidence a human will freeze or burn depending on where they land. (Observation notes)

By creating time for students to add to their evidence journals at the end of each lesson, Richie provided students with regular opportunities to reflect on their learning and explicitly identify ideas that related to the inquiry question "Can humans live on Mars?" A sample entry is provided in Table 3.

Table 3. Sample student entry after modelling geyser activity on Mars

Activity	What we observed	How does this add to my theory? What is your evidence? *"This suggests it is/is not possible to live on Mars because …"*	Questions I still have—*this can be anything related to living on Mars*
Identifying landforms on	*We went to a website which told us all the information about*	*The theory is that it is usually created by sunlight and geysers. Geysers are explosions that happen when* CO_2 *is*	*Can we survive these explosions*

the surface of Mars.	*landforms. There are heaps of landforms in mars.*	*trapped inside creating pressure and finally releasing which creates a massive explosion, but scientists still don't know how big the explosion is.*	*or convert the* CO_2 *to Oxygen?*

As a final assessment, students completed a report using a writing scaffold that Richie prepared with support from one of the school's English teachers. The scaffold included an example of a response using Venus as an example of a planet that is too hot for humans to inhabit. The scaffold required that students:

> Complete this sentence:
> I think humans can/cannot live on Mars.
> Write as many statements as you can using evidence to justify them using the following:
> Statement:
> Evidence:
> Impact on humans living on Mars:
> Importance to humans:
> Compare your statements. Which of these statements has the strongest evidence? Why?

Of the 29 reports that were completed and submitted, 15 students (52%) argued that humans cannot live on Mars, and 15 argued that students can live on Mars—although the majority of these (11) added that this "was very unlikely" or that it would not be "for a very long time". Of the students who argued that we cannot live on Mars, all 15 (100%) discussed the air composition and the lack of sufficient oxygen; 12 (80%) discussed the temperature impacts, referencing the distance from the sun and/or the increased level of carbon dioxide in the atmosphere, forming a greenhouse effect; 11 (73%) referred to the physical dangers from meteorites, asteroids, and/or geysers (demonstrating the impact of the classroom discussions focusing on these in relation to Planet Four and the modelling experiments); 10 (67%) referenced the absence of liquid water; and 10 (67%) referenced challenges with food production. Other reasons for why we cannot live on Mars related to the impacts of dust storms (six), the distance of travel (five), radiation effects (three), the resources we'd need to take from Earth (two), and the cost (two).

An example of a response from Student A focused on the atmosphere on Mars, drawing on website research, classroom resources, and learning in the unit:

> **Statement #2: Mars has a thin atmosphere.**
>
> **Evidence**: There is a lot of carbon dioxide on the surface of mars, 95.32%. However, there is barely any oxygen at 0.174%. Even after all this, the entire mars atmosphere

> is only 1% as dense as that of earths. I know this because I compared the charts between earth and mars.
>
> **Impact**: This thin atmosphere can easily cancel regular breathing and limit us to spacesuits.
>
> **Importance**: To even transport large amounts of oxygen to mars, it would take immense time. (Punctuation and capitalisation errors have been retained.)

The majority of students who indicated that humans might one day be able to populate Mars discussed evidence that points to the challenges facing human habitation of Mars but argued that future technological advances would address these challenges. For example, Student B's first argument acknowledges that humans need water, but points to scientific evidence of ice on Mars. The "solution" in this case relies on "increasing the [M]ars temperature":

> **Statement #1: I think you can convert ice into liquid.**
>
> **Evidence:** There used to be water on the mars surface but now it is gone but the rovers have found clay on mars so we know that before there used to be water on mars. In some shaded areas there are ice formats which can be converted into water. At the north pole and south pole there is a thick layer of sheets and dust and ice. We will convert ice into water by probably increasing the mars temperature, which would melt the ice in mars, creating water.

Student C focused their response on the importance of ongoing scientific discoveries. Their response also indicates the important learning about the nature of science as an ongoing cultural endeavour as a result of engaging with the *Planet Four* scientist:

> **Statement #4: We don't know a lot of things about Mars.**
>
> **Evidence:** Even though Mars has been closely studied for years and years, we still have no idea what may be lurking on the surface of the red planet. We have spoken to an astrologist, who specializes in studying Mars and is the chief scientist of a website that is based on classifying the different landforms on Mars. She told us about how scientists still don't know many things about Mars; like people who are studying Mars don't know that much about Martian Geysers. They don't know if they produce sound or how loud it is, they don't don't know what the average height of a geyser is, they don't know if the gravity is being affected by the explosions caused by the geyser on Mars, and many more.

The final report template also asked students to "Compare the statements. Which of these statements has the strongest evidence? Why?" While some students cited their sources (e.g., websites), the majority responded to this question by ranking their responses as being the most important/least important reason (i.e., evidence) for why humans can or cannot live on Mars. For example, Student D wrote:

> Statement two [The atmosphere of Mars is completely different to that of earth's] in my eyes is the most important because it's the most difficult to overcome since we can't even imagine technology that could do what we want to do. It's also a necessity that we need to live.

Discussion and conclusion

When scientists investigate, they bring considerable conceptual understanding and procedural knowledge to designing their investigation with the intention of generating new knowledge. School science is different in that students are learning about the scientific knowledge generated and consensually agreed by scientists (Osborne, 2019). They are also developing the science capabilities to Gather and interpret data, Use evidence, Critique evidence, Interpret representations, and Engage in science (Hipkins & Bull, 2015). During this project, students learnt about Mars—its atmosphere, climate, landscape, resources, distance from Earth, and its position in the solar system. They were also challenged to use their knowledge about the conditions for life on Earth and compare this with what they were learning about the conditions on Mars. They were consistently encouraged to identify and use evidence in their arguments, while also being creative about how life may be possible on Mars in future. In other words, the unit plan integrated learning outcomes related to conceptual understanding and science capability development.

Richie's enthusiasm for the project and willingness to try a novel approach to the school's Year 9 astronomy unit led to the use of the OCS project Planet Four as an anchor in the unit's design. In order to scaffold students' engagement with Planet Four in the unit, the students carried out a range of hands-on activities and also "met" one of the leading Planet Four scientists online. Teacher enthusiasm generates student intrinsic motivation (Patrick et al., 2000), and the topic was also of interest to the vast majority of the students. The inquiry question "Can humans live on Mars?" provided a thought-provoking context for focusing learning about both key features of Mars and the students' ability to identify and use evidence. The teacher notes that "How do you know?" became a "mantra" in his class, and multiple examples of in-class questioning evident in the classroom observations align with the Ministry of Education's (n.d.) description of the science capability Use evidence:

Students should be encouraged to ask and answer questions such as:

- How do you know that?
- What makes you think so?
- How could you check that?
- So, an example of this would be ...
- Can you think of an example when this wouldn’t work?

Participation in authentic scientific projects that explore questions that are yet to be answered are more likely to engage students than the recipe practicals taught in schools (Paige et al., 2016). Engaging with Planet Four, including meeting one of the project’s scientists, became an important anchor for the learning across the unit, as did the inquiry question. The value of scaffolding students’ engagement with the OCS project and embedding this learning in the wider unit was also evident—a theme that has been strongly identified in other research investigating school student engagement with OCS projects (e.g., Brunvand & Bouwman, 2018; Authors; Schuttler et al., 2019).

Commented [SC3]: Delete? Or are there other authors to add?

Learning through the unit was multifarious, presenting students with opportunities to read science, write science, do science (e.g., using models, investigating crater formation), and use representations as proposed by Osborne (2019). The daily evidence journal provided an important mechanism through which students practised identifying and thinking about evidence and reflecting on their learning. Writing scaffolds for both this evidence journal and the end-of-term report provides students with a framework to think with and write in. As teachers of science, teaching the language of science and being able to communicate scientific thinking through writing is also science teachers’ responsibility. The use of the inquiry question helped to make the learning more personal.

Given the interpretive case study approach adopted in this study, only “fuzzy generalisations” are possible (Bassey, 2001, p. 5). However, we hope that sufficient detail has been provided to evidence the ways in which the unit played out with these Year 9 students, and some of the impacts on their engagement and learning. Importantly, this case study demonstrates some ways in which the science capabilities might form an explicit component of teaching and learning in secondary school science. It also contributes to the nascent literature reporting on the impacts of embedding OCS projects in school education programmes.

In relation to the science capability Use evidence, we acknowledge the multiple strategies that were woven throughout the unit to continually and explicitly emphasise this aspect of science. Osborne (2014) points to improvements in conceptual learning when students engage in argumentation using evidence. A next step would be to continue to pursue a deliberate focus on using evidence in other units, widening the range of contexts in which students continue to develop this capability; also to deliberately look for opportunities to link the capability Use evidence with the other capabilities: Gather and interpret data, Critique evidence, Interpret representations, and Engage with science. Engaging with OCS projects as part of wider units of learning could be one way of doing this.

Acknowledgements

This case study has been developed as part of the larger project, On2Science—Multiple affordances for learning through participation in online citizen science, funded by New Zealand's Ministry of Education's Teaching and Learning Research Initiative. We gratefully acknowledge this funding, the willing contributions of Richie's students, and the support and insights of the rest of our 2020 research team: Matt Boucher, Carol Brieseman, Rose Campbell, Dianne Christenson, Melissa Coton, Cathal Doyle, Brigitte Glasson, Rosemary Hipkins, Yevgeniya (Jane) Li, Cameron Pierson, and Stephen Ross.

References

Allchin, D. (2017). Beyond the consensus view: Whole science. *Canadian Journal of Science, Mathematics and Technology Education, 17*(1), 18–26. https://doi.org/10.1080/14926156.2016.1271921

Anderson, D., Buntting, C., & Coton, M. (2020). Using online citizen science to develop students' science capabilities. *Curriculum Matters, 16*, 38–59. https://doi.org/10.18296/cm.0047

Aristeidou, M., & Herodotou, C. (2020). Online citizen science: A systematic review of effects on learning and scientific literacy. *Citizen Science: Theory and Practice*, *5*(1), 1–11. https://doi.org/10.5334/cstp.224

Bassey, M. (1999). *Case study research in educational settings*. Open University. https://doi.org/10.1080/03054980123773

Bassey, M. (2001). A solution to the problem of generalisation in educational research. *Oxford Review of Education, 27*(1), 5–22.

Brunvand, S., & Bouwman, J. (2018). A global perspective: Fifth graders practice data collection as they examine soil. *Science and Children, April/May*, 50–55. https://doi.org/10.2505/4/sc18_055_08_50

Commented [JH4]: Here and elsewhere I've added dois where available

Bull, A. (2015). *Capabilities for living and lifelong learning: What's science got to do with it?* New Zealand Council for Educational Research. https://www.nzcer.org.nz/system/files/Capabilities%20for%20living%20and%20lifelong%20learning%28v2%29.pdf

Chen, J., Cowie, B., & Schipper, A. (2012). A butterfly story: Being a citizen scientist. *New Zealand Science Teacher*, *130*, 34–37.

Eitzel, M. V., Cappadonna, J. L., Santos-Lang, C., Duerr, R. E., Virapongse, A., West, S. E. et al. (2017). Citizen science terminology matters: Exploring key terms. *Citizen Science: Theory and Practice*, *2*(1), 1–20. https://doi.org/10.5334/cstp.96

Hipkins, R., & Bull, A. (2015). Science capabilities for a functional understanding of the nature of science. *Curriculum Matters*, *11*, 117–133. https://doi.org/10.18296/cm.0007

Kloetzer, L., Schneider, D., Jennett, C., Iacovides, I., Eveleigh, A., Cox, A., & Gold, M. (2013). Learning by volunteer computing, thinking and gaming: What and how are volunteers learning by participating in virtual citizen science? In: *Proceedings of the 2013 European Research Conference of the Network of Access, Learning, Careers, and Identities, European Society for Research on the Education of Adults (ESREA)* (pp. 73–92), Linköping, Sweden.

Ling, L., & Ling, P. (2017). *Methods and paradigms in education research*. IGI Global. https://doi.org/10.4018/978-1-5225-1738-2

Ministry of Education. (2007). *The New Zealand curriculum*. Learning Media.

Ministry of Education. (2019). *Science in the New Zealand curriculum: Understanding progress from levels 2 to 4*. http://scienceonline.tki.org.nz/Progress-and-Achievementin-Science

Ministry of Education. (n.d.). *Science capabilities for citizenship*. https://scienceonline.tki.org.nz/Science-capabilities-for-citizenship

OECD. (2019). PISA 2018 science framework. In *PISA 2018 assessment and analytical framework*. OECD Publishing. https://doi.org/10.1787/f30da688-en

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education*, *25*(2), 177–196. https://doi.org/10.1007/s10972-014-9384-1

Osborne, J. F. (2019). Not "hands on" but "minds on": A response to Furtak and Penuel. *Science Education*, *103*(5), 1280–1283. https://doi.org/10.1002/sce.21543

Paige, K., Zeegers, Y., Lloyd, D., & Roetman, P. (2016). Researching the effectiveness of a science professional learning programme using a proposed curriculum framework for

Commented [SC5]: Page numbers?

schools: A case study. *International Journal of Science and Mathematics Education*, *14*(1), 149–175. https://doi.org/10.1007/s10763-014-9569-2

Patrick, B. C., Hisley, J., & Kempler, T. (2000). "What's everybody so excited about?": The effects of teacher enthusiasm on student intrinsic motivation and vitality. *The Journal of Experimental Education*, *68*(3), 217–236. https://doi.org/10.1080/00220970009600093

Pierson, C. M., Anderson, D., Luczak-Roesch, M., Doyle, C., Glasson, B., Li, Y., Brieseman, C., Boucher, M., Christenson, D., & Coton, M. (2020). Developing science capabilities for citizenship through participation in online citizen science (OCS) projects. *Set: Research Information for Teachers*, (1), 19–26. https://doi. org/10.18296/set.0157

Schuttler, S. G., Sears, R. S., Orendain, I., Khot, R., Rubenstein, D., Rubenstein, N. et al. (2019). Citizen science in schools: Students collect valuable mammal data for science, conservation, and community engagement. *BioScience*, *69*, 69–79. https://doi.org/10.1093/biosci/biy141

Ylizarde, H., & Shockley, T. E. (2018). Nurturing local-to-global thinking. *Science and Children*, *55*(8), 44–51. https://doi.org/10.2505/4/sc18_055_08_44

Commented [SC6]: Not cited in the article.

Zooniverse. (n.d.). *Planet four*. www.zooniverse.org/projects/mschwamb/planet-four

The authors

Dr **Cathy Buntting** (corresponding author) is Director of the Wilf Malcolm Institute of Educational Research, University of Waikato, and co-leads the TLRI-funded project from which this case study emerged. Her research focuses on curriculum and pedagogical support for science and STEM teachers.
Email: cathy.buntting@waikato.ac.nz

Dr **Azra Moeed** is an Adjunct Professor at Ako Pai o Te Herenga Waka, the Faculty of Education at Victoria University of Wellington. In her roles as a science teacher, science teacher educator, and researcher, she especially enjoys learning with students and colleagues.

Dr **Dayle Anderson** is an Adjunct Research Fellow at Ako Pai o Te Herenga Waka, the Faculty of Education at Victoria University of Wellington. She has worked as a scientist, primary teacher, deputy principal, and teacher educator. Her research continues to focus on the use of online citizen science in classrooms and ways to support integrated science, drama, and literacy learning.

Richie Miller teaches science and biology at Newlands College, bringing to his lessons enthusiasm and expertise from former careers in geology and environmental science. He is passionate about showing students that science is varied and can take you to different places.