USING ONLINE CITIZEN SCIENCE TO DEVELOP STUDENTS' SCIENCE CAPABILITIES

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ABSTRACT

In 2018, a research project funded by New Zealand's teaching and learning research initiative (TLRI) explored the impact of online citizen science (OCS) projects on the science education of primary school children in New Zealand. This article provides an in-depth case study from this project in order to share ways in which one teacher used OCS projects specifically to develop students' science capability, 'critique evidence'. Comparing data from students' conversations and work with the progress indicators for the science capabilities released by the Ministry of Education in 2019 suggests that many of the students were achieving at or above the expected level. We suggest that teacher professional learning and development in relation to the intent of science in the NZC, and the purpose of the science capabilities, was a significant enabler.

INTRODUCTION

The TLRI-funded research reported in this paper, *Citizen scientists in the classroom: Investigating the role of online citizen science in primary school science education,* brought together an interdisciplinary team of education and information science researchers, teacher professional learning providers, and teacher practitioners. The aim was to explore the impact of participating in online citizen science (OCS) projects on the science education of primary school children in New Zealand, and to consider how such projects could be usefully embedded in classroom programmes (Luczak-Roesch, Anderson, Glasson, Doyle, Li, Y., Pierson, & David, 2019). Citizen science can be generally defined as "scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and science institutions" (Eitzel, Cappadonna, Santos-Lang, Duerr, Virapongse, West, et al., 2017). Online citizen science (OCS) projects are citizen science projects in which participants engage with at least some aspects of the project via the Internet. Our research focused on: identifying OCS projects that are aligned with the NZ science curriculum and are suited for use in the classroom; examining how OCS projects can be effectively embedded in primary classroom programmes; and identifying some of the learning benefits that can result, including development of students' science capabilities (gather and interpret data, use evidence, critique evidence, interpret representations, and engage with science; for more detail see below). This paper presents an in-depth case study of how Melissa (the third author) used OCS projects specifically to develop her students' ability to critique evidence.

SCIENCE IN THE NEW ZEALAND CURRICUM

The vision of The New Zealand Curriculum (NZC) is for young people "who will be confident, connected, actively involved, and lifelong learners" (Ministry of Education, 2007, p. 8). Schools are responsible for developing their own place-based curriculum guided by the NZC, integrating eight learning areas with the development of five key competencies (thinking; using language, symbols and text; managing self; relating to others; and participating and contributing). In science, it is intended that students will "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). To this end, the science learning area positions 'Nature of Science' (NOS) as the overarching, unifying strand through which "students learn what science is and how scientists work" (p. 28). This learning is to take place within the major contexts in which scientific knowledge develops: the living world, the material world, the physical world, and planet earth and beyond.

Recognising the complexity involved in pulling the multiple curriculum elements together the Ministry of Education (n.d.) published five science capabilities for citizenship: gathering and interpreting data, using evidence, critiquing evidence, interpreting representations, and engaging with science. These capabilities and the accompanying resources were therefore introduced to explicitly demonstrate how teachers might 'join the dots' between all of the following:

- the content strands of the science learning area
- the 'overarching' NOS strand
- the essence statement that foregrounds the citizenship purpose for learning science
- the key competencies
- some existing resources designed to support learning in science. (Hipkins & Bull, 2015, pp. 125-126)

In other words, the science capabilities were developed as "resources for teachers to 'think with', when planning, working with students, and when reflecting on the learning actually achieved" (Hipkins & Bull, 2015, p. 126).

To support teachers to engage with the science capabilities, comprehensive examples of how each capability might be developed were published based on existing science education resources (Ministry of Education, n.d.). These examples were positioned from Curriculum Levels 1 through to 5. However, evidence of how students actually make progress in developing their science capabilities is only beginning to emerge. For example, Bull (2015) reports on a small research study in which students from Years 1-10 in a range of New Zealand schools completed some of the assessment tasks published as part of the original science capabilities initiative. Assessment useful in guiding and showing progress often draws on defined gradations or steps within progressions, whereas the science capabilities are more global in nature. To address the need for teachers and schools to show and report on progress, Bull suggested using overall teacher judgements of how closely each student resembles an ‘ideal’ profile, with assessment tasks focusing on identifying next learning steps. The ‘ideal’ profiles, represented in Bull’s paper by Izzy (Levels 1-2), Hugo (Levels 3-4) and Pippi (Level 5), are intended to provide teachers “with ideas about how to further extend their students”, with the advantage “of maintaining the holistic nature of capabilities” (p. 11).

Additional insights into how students might progress in their science capability development were obtained from the National Monitoring Study of Student Achievement [NMSSA], which in 2017 focused on science and was substantially based on the science capabilities for citizenship. Nationally representative samples of over 2,000 students at Year 4 and Year 8 from 100 schools completed a series of paper and pencil-based group-administered tasks, and a subset of approximately 800 students at each year level completed further in-depth open-ended response practical tasks, all administered by specially trained NMSSA assessors. The findings of this study were interrogated to explore students’ progress with the science capabilities, resulting in a series of indicators for each of the science capabilities at Levels 2 and 4 (Ministry of Education, 2019). These indicators were published after the study reported here was completed, but they form a useful point of comparison for the science capabilities evidenced by student participants.

ONLINE CITIZEN SCIENCE IN EDUCATION

The number of online citizen science (OCS) projects has grown rapidly in recent years, giving anyone with a digital device access to real-life science research projects. While the term ‘citizen scientist’ is not without contention, it has nonetheless become widely used within the domain, and tends to be generally described as any participating member of a broadly construed community contributing in some way to a scientific investigation (Eitzel et al., 2017). Increasingly, school teachers are tapping into both citizen science and OCS projects as a novel way to promote interest and engagement in science as well as important learning of and about science concepts and processes in an authentic context.

While there is a growing literature reporting the impacts of engaging in local, or even globally-connected citizen science projects, fewer published studies report on the impacts of student participation in citizen science projects that have a significant online component. Where they do exist, the reports tend to focus primarily on teacher practice, highlighting the scaffolding that is needed for learning opportunities to be maximised. Reports also regularly comment on the positive impacts of participating in ‘real science’ on student engagement, with some studies exploring the gains in students’ conceptual, procedural and epistemological learning.

For example, a study by Schuttler et al. (2019) showcases the capabilities of students from different regions to follow scientific protocols. In this project, students aged 9-14 in the USA, Mexico, India and Kenya learned to set infrared motion-activated cameras and upload photographic data to eMammal, an online data management system and archive for camera trap research projects. Engaging with the eMammal platform presented multiple opportunities for student learning: posing scientific questions, collecting scientific data, connecting with nature, learning about their local environment, getting expert feedback (each identification is reviewed), contributing to a larger dataset (uploaded photographs are archived), and impacting the wider community by sharing the findings. In this instance, the teachers reported that eMammal engaged their students, provoked their curiosity, and "gave their classroom activities meaning and purpose, resulting in the students' setting cameras more carefully and caring about the data" (p. 76).

A study by Brunvand and Bouwman (2018) similarly reported that by contributing to and using a larger dataset, students became "respectful stewards of data" (p. 54). Their study was of Michigan fifth graders' engagement with the Soil Moisture Active Passive (SMAP) pedosphere protocol hosted by GLOBE (Global Learning and Observations to Benefit the Environment): students made decisions about where to collect data, followed the GLOBE sampling protocols, and uploaded their data onto the global platform. Through this OCS project, they engaged in scientific research and contributed to a larger global project with genuine scientific value. During the unit, the students also accessed a wider data set via GLOBE's Advanced Data Access Tool to conduct their own science-related investigations, including posing hypotheses; working out which data they would need; retrieving, analysing and interpreting the data; and sharing their findings with their classmates. The project thus presented students with multiple opportunities for learning, collecting their own data as well as interrogating the data provided by others.

Other researchers have reported on enhanced student engagement and enthusiasm when engaging with OCS projects like uploading multimedia nature journals to Project Noah (Zydney & Schaen, 2018), or carefully observing and tagging photographs of wildlife on the Zooniverse and Tomrod OCS platforms (Ylizarde & Shockley, 2018). In a New Zealand study, Year 4 students (8-9 year olds) engaged with a national citizen science project tagging and logging the location of Monarch butterflies as part of a wider unit on butterflies (Chen, Cowie, & Schipper, 2013). This study again highlighted the scaffolding provided by the teacher, exploring how students were supported to talk, think, and act as citizen scientists, but it also examined the impact on students' learning, interest and actions. In addition to learning about butterfly life cycles, students asked scientific questions, made observations, developed topic-specific scientific language and suggested explanations for patterns in data. Participation in the OCS project also enabled them to take action as citizen scientists. Interviews with students immediately following the unit and again six months later revealed that students had maintained their interest in and respect for butterflies, which was framed within a wider desire to respect and protect other endangered animals and the environment. The study highlighted the mutually beneficial learning opportunities for science and citizenship that are created through such a participatory approach.

Each of the projects referred to above showcases the potential of OCS projects to enable the weaving together of content with wider curriculum goals in ways that are accessible to young learners. However, teacher scaffolding is integral if multiple curriculum goals are to be addressed. For example, each study highlights the importance of embedding the OCS engagement within a wider unit of teaching and learning. Considerable value was also gained through students being able to contribute to scientific projects that reached beyond their classrooms and schools to a broader community with interest and expertise. The TLRI-funded research project reported here sought to shed light specifically on the impact of online citizen science (OCS) projects on the science education of primary school children in New Zealand. In particular, it explored ways to embed OCS into primary science programmes and the impact on primary students' science capability development (Luczak-Roesch et al., 2019). This paper reports on the ways in which one of the teachers, Melissa, used OCS projects as part of a wider science unit about light, to help students develop their ability to critique evidence.

RESEARCH METHODOLOGY

The wider TLRI study adopted an exploratory multiple case-study approach, of which one of the cases is reported here. As part of the wider study, each teacher embedded an OCS project within a science unit. As part of their planning, teachers reviewed possible projects and selected one that they felt would appeal to their students and that was aligned with the topic and goals of the unit. The teachers were also asked to include a focus on one or more of the science capabilities. The units were implemented over the course of a term. Data included teacher planning documents; classroom observations when the OCS was being introduced and used; teacher oral and written reflections prior to, during and post-unit; student post-unit questionnaires and focus group interviews; and samples of student work. Analysis of the data was conducted using NVivo software, both inductively to identify themes and deductively using the science capabilities for citizenship as a framework (Ministry of Education, n.d.). Initial coding was reviewed independently by two additional researchers and a high degree of inter-rater agreement was achieved. In this paper, we describe the way Melissa embedded the OCS and supported development of her students' ability to critique evidence. We then draw on observational data and students' questionnaire responses and work samples to indicate their developing ability to critique evidence.

Case study details: Participants and setting

At the time of the research reported here, Melissa was in her 8th year of teaching. She talks of always having been interested in science, and remembers loving the hands-on science she experienced at school. When she became a teacher, she wanted to inspire the same sense of wonder and curiosity that she had experienced. In 2015, she completed a Postgraduate Certificate in Primary Science Teaching through the Open Polytechnic of New Zealand, and in 2016 she participated in the Science Teaching Leadership Programme (STLP) funded by the Ministry of Business, Employment and Innovation and administered by the Royal Society - Te Apārangi. Through this programme, she had received professional development focusing on the science capabilities as well as other aspects of science education and leadership. Melissa felt the STLP supported her to develop a good understanding of the science capabilities and how to support students to develop them. She considered the science capabilities framework as a way of supporting teachers to integrate the content strands of the science curriculum learning area and the overarching Nature of Science strand. She felt they shifted the focus of science learning in the classroom away from knowledge development and towards developing skills and dispositions that are transferable across all scientific contexts. Prior to participation in the 2018 OCS intervention she had included an explicit focus on the capabilities in her science units and activities, but this had been in a previous school working with Yr 7-8 students. Melissa had recently changed schools and this unit was the first science-focused inquiry unit she was teaching with the case study class.

The case study class comprised 27 Year 5/6 (9-11 year old) students (14 boys and 13 girls), of whom 17 identified as New Zealand European, five as Pasifika, three as Asian and two as Māori. The school is situated in a low-middle socio-economic suburban area. The class was taught in a single cell classroom with desks arranged in pairs or fours around a mat area used for whole class teaching and discussions. The students were new to using the school-provided chromebooks as these had not been used in more junior classes. They worked either in pairs or individually on a single device to access the OCS.

The teaching and learning programme

Melissa chose the OCS project 'Globe at Night' to support a wider unit on the physics of light that she was intending to develop for her class. Globe at Night (www.globeatnight.org) is an international citizen science campaign developed in the US by the National Optical Astronomy Observatory and operated by the Association of Universities for Research in Astronomy with support from the National Science Foundation. The intention is to raise public awareness of the impact of light pollution by inviting citizen scientists to measure and submit night sky brightness observations. In submitting their data, citizen scientists contribute to the accumulation of ground-based data about light pollution. To contribute, citizen scientists identify particular constellations in their night sky; submit data about the time, location and cloud cover; and match the magnitude of star brightness to magnitude charts provided. The project provides annual data sets from 2006.

Melissa chose to use Globe at Night because:

> It linked with our Physical World unit on light. Focusing on light pollution provided a context to apply and deepen our growing knowledge about light. I was excited that Globe at Night gave students an opportunity to gather their own data, which they could then contribute to a global dataset. (Post-unit written reflection)

In addition, she reported:

> My students were already very interested in astronomy, and I thought the context would be highly engaging. I also thought a focus on light pollution would provide lots of opportunities for students to take action as a result of their learning. A huge retirement village development is planned for land at the back of our school field – discussing how the light generated by hundreds of new units could have an impact on the people and animals in our local area proved to be really engaging. (Post-unit written reflection)

Melissa used the OCS to anchor the unit, which began with a series of practical investigations exploring the properties of light. Prior to introducing the OCS the students developed their own inquiries into the nature and impact of light pollution and Melissa invited a scientist involved in developing a Dark Skies area in a nearby region to talk with the students. Melissa linked students' learning about light to their local context:

> We took a lot of opportunities to look at footage of beautiful night skies, completely free of light pollution. And I guess that kind of helped them to realise what they're missing out on, living in a suburban area that actually has a lot of light pollution...coming into class telling me about the light pollution they saw in Wellington over the weekend really helped to build their enthusiasm and their engagement. (Post-unit reflection)

Next, the OCS project was introduced using a video available from the Globe at Night website, followed by an online 'treasure hunt' that Melissa created to help students become familiar with navigating the website. Melissa then used the website's resources to support the students to learn to recognise constellations and prepare them to make observations of the night sky in their area. Part of this preparation included discussing and practising making judgements about light magnitude using the magnitude charts provided by the project. Unfortunately adverse weather conditions during the period that actual observations were to be made meant there was no opportunity for students to record their own observations. While extremely disappointing for everyone, Melissa was able to use a photo that she took herself at 3am one morning during a brief clear moment. Students used the magnitude charts from the website to estimate the amount of light pollution.

Next, Melissa used the data presented on the website in class activities that supported students to critique evidence, as described below in the findings section. The class also examined other OCS projects in different contexts, one about orangutans and one about monarch butterflies, to continue to develop the students' ability to critique evidence. Following these activities, the students undertook two assessment tasks focused on the critiquing evidence capability. The first was a written question and answer task that Melissa designed herself, based on the activities the students had completed using the Globe at Night. The second task was designed to examine the 'critiquing evidence' capability in the context of floating and sinking from the Assessment Resource Banks (NZCER, n.d.). In the final stages of the unit, the students used their learning about light pollution to examine different forms of street lighting and wrote to their local council and developers, taking action about the choice of lighting in the large retirement village planned near their school that could drastically increase the amount of light pollution in their area.
The inquiry unit was spread over the second school term (approximately 10 weeks). Early in the next term, interested in whether the students' developing ability to critique data was sustained and would transfer to other contexts, Melissa used the OCS 'Beluga Bits' as an informal follow-up assessment task.

FINDINGS

Supporting students to critique data: Using Globe at Night

Melissa had determined during her planning that she wanted to focus on this capability, realising that Globe at Night provided opportunities for her students to develop a range of science capabilities. Her early planning also showed the support and scaffolding she recognised would be needed to help her students to gather data for the project:

- Practising locating constellations and making judgements about light magnitude using the magnitude charts provided by the project
- Communicating with parents and whānau (family) about making observations at home/in the community after dark
- Providing alternatives (photos / film of local area) for making first hand observations for those students who would not be able to do so themselves. (Pre-unit reflection following selection of OCS)

Melissa designed three activities, described below, that would specifically support her students to develop their ability to critique data using Globe at Night. She then drew on other OCS projects to further support their learning.

Deciding on star magnitude: Familiarising students with data collection processes and interpretation

As stated earlier, the weather unfortunately precluded the students making and using their own observations, so Melissa used a photograph she had taken of the night sky for the children to work with in applying the magnitude criteria provided by Globe at Night:

> All students made independent judgements about the magnitude of the stars visible in the photo. Even though the project provides detailed guides to support judgements, there was a lot of disagreement about which magnitude to place photos. This was very helpful in supporting students to develop an understanding of the inherent difficulties associated with collecting data via any method that relies on individual judgement. (Mid-unit reflection)

The discussions and disagreements amongst students were recognised, valued and explicitly explored as a class. As such, Melissa reinforced an expectation that students should be critical about what they were seeing and doing, i.e., developing a 'sceptical stance' (Ministry of Education, n.d.).

Looking for patterns in project data and suggesting explanations for missing data

The Globe at Night website includes data collected over more than ten years, with world maps for each year showing the location and degree of reported light pollution globally. Melissa recognised the opportunities presented by this data set, and used it to continue to build students' experiences. First, she asked the students to work in pairs and see what patterns they could see in the data, recording their ideas on sticky notes that they displayed on the wall. Melissa's instructions and questioning supported students to think critically about the data, for example:

> "I'd like you to focus on what are the patterns that you notice. And how many different observations were made at different times."
> "What did you notice about the data?"
> "Now I'd like you to think about what's missing." (Classroom observations)

As students reported back, she noticed their observations and ensured the rest of the class heard and considered the implications of students' observations:

Student 1: China has lots of people but there are no reports from there. It [light pollution] might be happening but no-one is reporting it.
Student 2: They speak a different language but the site is in English, so that might explain it.
Melissa: That's very important thinking: it might be happening but no-one is reporting it....
Student 3: In 2006 Wellington had no light pollution.
Melissa: But does that mean Wellington didn't have light pollution then?
Student 3: No, just that no one reported it.

This interaction is indicative of many of the classroom interactions that Melissa facilitated, indicating that she often incorporated questions and ideas similar to prompts suggested by the science capabilities teacher support website (Ministry of Education, n.d.). In this particular case, the questions focused on students' critical consideration of the data and its reliability.

Comparing light pollution data from different sources

In the third activity designed to support students to critique evidence, Melissa asked students to compare the maps on Globe at Night with maps generated from light intensity data gathered by satellite (www.lightpollutionmap.info). The students were asked to decide which dataset they would prefer to use if they were scientists investigating light pollution. Students immediately noted differences between the two data sources, and the activity generated productive discussion about the limitations of Globe at Night as a data-gathering platform with its reliance on data that resulted from interpretation by many different people. Asking children to "think like scientists" was an important connection, too, as it associated the kind of critique they were doing as being valuable within the discipline of science: while developing their own ability to engage effectively with science, they were learning about science itself.

Using other OCS projects

In a deliberate effort to support students to continue to develop their ability to critique evidence in new contexts, Melissa included follow up activities in which the class explored other OCS projects. The first, *Orangutan Nest Watch* (https://www.zooniverse.org/collections/olenglish/orangutan-nest-watch), helped students develop a deeper understanding of citizen science by engaging with a project that required them to help scientists interpret data. Melissa then used the butterfly tagging project of the *Monarch Butterfly New Zealand Trust* (https://www.monarch.org.nz/) as another context to develop students' skills at critiquing evidence. Melissa led a discussion about the reliability of the data collected, which connected closely with discussions about the reliability of Globe at Night data. Students were specifically asked to consider the data gathering method and reliability of data. For example, they suggested that people who are interested in butterflies would sign up to tag them, and that it could be very difficult to find butterflies that have been tagged.

Evidence of science capability development

Melissa reported that this unit was the students' first planned opportunity to develop the science capability of critiquing evidence. Although no pre-unit data were collected, students' responses to the classroom activities described above and a written assessment task showed that many students were able to identify important discrepancies within the Globe at Night datasets, and to discuss aspects of data reliability.

For example, students' comments during the pattern seeking exercise described above included:

> "Big cities are where most people are… so they might get most reports"
>
> "One person in Australia may have been doing all the reporting - it's the same place each year." (Classroom observation).

Students' comments recorded on the sticky notes included:

> "There (sic) mostly in bunches and in countries that are busy" and
>
> "It is coming up at the same place and it is mostly in United States and Urip (sic)",

with more critical statements such as:

> "Most of the biggest countries in the world have apparently NO light pollution" and
>
> "There is no data from China but that does not mean there is no light pollution there."

Seven of 15 sticky notes produced by groups or individuals described patterns and 10 notes suggested a critiquing of the data (two included both pattern noticing and critique); just four sticky notes only noticed patterns. Two also made interpretations which suggested action was needed:

> "The number of observations have increased. Countries are getting 'richer' with light so most of the humans don't think about light pollution."

The written assessment task identified the learning intention as 'Think critically about data' and revisited classroom conversations. The questions highlight Melissa's focus on students' ability to critique evidence:

1. What patterns did you notice on the data maps
2. What is missing? Why might this be?
3. How was the data collected?
4. How reliable is data collected this way?
5. Brainstorm things that could affect the reliability of data collected this way.
6. If you were a scientist, would you rather use data from the Globe at Night site or the satellite generated data? Why?

Five representative samples of the completed assessment provided by Melissa for the project were analysed in detail. All these students showed they understood the process of data collection for Globe at Night. Four of the five were able to identify specific data that was missing, identifying that many large countries showed no light pollution, and proposed reasons such as language being a barrier. One student also identified that there were fewer observations than expected, perhaps because people were not interested in light pollution. All thought the data were not very reliable, identifying human error as a significant issue: "making mistakes", "not doing it", "just guessing", or "being silly". However, one student also pointed to issues such as "weather, poor countries, no equipment, fake data." All five students identified the satellite data as being more reliable because it showed more data and "you can trust technology more than people".

In post-unit interviews and questionnaires, students generally identified their learning from the OCS project as being about light pollution and its effects on animals and people. This is not unexpected as many used the website for this purpose, and young students tend to recognise new conceptual learning more readily than growth in procedural or epistemic understanding (Anderson, 2012). Interestingly, critiquing evidence was the capability least recognised by students right across the wider TLRI project; students more often recognised that they had learned to observe carefully.

Melissa reported after the unit that students were able to transfer their ability to gather and interpret data and to critique data to another context, floating and sinking, using an assessment task from the Assessment Resource Banks (NZCER, n.d.). However, she was curious to see if students would be able to transfer their ability to critique evidence and think critically about the reliability of data gathered/interpreted via OCS projects. She therefore introduced students to the OCS 'Beluga Bits' as another informal post-unit assessment task early in the following term. On the whole, students were not able to independently critique evidence in this novel context, and Melissa felt that further opportunities were needed for students to consolidate their ability to critique evidence.

Linking student capability development with the progress indicators

As indicated earlier, draft progress indicators for the science capabilities for Levels 2 and 4 (Ministry of Education, 2019) were released after Melissa's classroom intervention. The indicators for 'critique evidence' are shown in Table 1. No indicators are provided for Level 2 because no data related to this capability and level emerged from the NMSSA data, and we wonder what the impacts are in terms of teachers' expectations for students working at this level. The students in Melissa's class were Year 5-6, and would therefore be expected to be working at Level 3 of NZC, although we need to note that Achievement Objectives for Level 3 and 4 of science in NZC are identical except for one Material World objective (Ministry of Education, 2007).

Comparison of the responses above with these indicators suggests that most students were able to identify a problem in data (Above Level 2). To varying degrees they were also able to check data for differences in patterns (Level 4), and to check data and identify possible sources of error (Above Level 4). Many were able to identify features of investigations that may not result in sound evidence - a corollary to the final indicator at Above Level 4. The study presented here therefore provides empirical evidence that 10-11 year olds are able to identify problems in data when working in a range of familiar and unfamiliar contexts, and that some can identify possible sources of error.

Table 1: Progress Indicators for the science capability Critique Evidence (Ministry of Education, 2019, pp. 6-7).

Level	Context and Indicator for Critique Evidence

Above Level 2	Students are testing their everyday knowledge. They work in a range of contexts, including some that are unfamiliar to: • identify a problem in data
Level 4	Students are building science knowledge. They often work in unfamiliar contexts to: • check data and explanations for differences in patterns
Above Level 4	Students are applying their science knowledge. They work in increasingly complex and unfamiliar contexts to: • check data and explanations to identify possible sources of error • identify what is not evidence in a science context • identify features of investigations that ensure they will result in sound evidence

These comparisons suggest that the capability development of a considerable proportion of Melissa's students was well above that of their 'expected' level. However, they also need to be considered in the light of the familiarity of the context and the complexity of the task - two factors considered important in making progress in capability development (Ministry of Education, n.d.). The context of comparing light intensity over time and place could be considered a sophisticated and perhaps unfamiliar context for these students. Through their experiences in learning how to gather and interpret data for Globe at Night, they had been alerted to the difficulties of interpretation and therefore to question the reliability of the data sets they were interrogating, suggesting that 'familiarity with the context' includes understanding of the processes involved in gathering and interpreting data in a given situation.

Further, many of the students were able to critique evidence in the task about floating and sinking where they were involved practically in gathering and interpreting data, but they were less able to apply their capability to a different OCS with which they had no experience of gathering and interpreting data. However, the task they undertook in critiquing the Globe at Night data-sets was complex. It required them to interpret maps and compare size and position of dots across different data-sets. They also needed to identify and bring to the task other relevant ideas, such as geographical and social knowledge of different countries, in order to suggest possible sources of error.

These students had undertaken learning experiences specifically targeting the development of this capability. Melissa reflected:

> My science teaching for this unit was different in terms of going deeper into developing a single specific science capability. I felt that the Globe at Night project was uniquely suited to supporting students to develop their capability to critique evidence and my planning and teaching reflected this. We covered protocols and investigation design in a more in-depth manner than I have done previously...We had rich discussions about the limitations of a science project that relies on citizen

> scientists to contribute data that is based on their personal judgements. (Post-unit reflection)

She also commented that her beliefs about the role of the science capabilities in guiding teachers' planning was "deepened further through the OCS projects and helped to reinforce for me how powerful a tool they [the science capabilities] are for science teachers and learners."

DISCUSSION AND CONCLUSION

This case study and the other three cases in the wider project provide compelling evidence that engaging with OCS projects can support students' science capability development, where this is an explicit part of the teaching and learning programme (Anderson et al., 2020; Luczak-Roesch et al., 2019; Pierson et al., 2020). In the case study presented here, Melissa specifically used Globe At Night to focus on students' development of the science capability 'critique evidence'. The unit included a variety of learning activities, including targeted questioning, to support students' ability to critique evidence. Melissa also went on to use other OCS projects to support the students to transfer and further develop their ability to critique evidence in new contexts. Empirical evidence that these 10-11 year olds were able to demonstrate an ability to engage critically with data is important for growing collective understanding of ways in which students might make progress in developing this science capability, which is central to the intent of the NZ Curriculum for science. As Osborne (2014) and Ford (2008) have argued, critique of new claims is pivotal in science, and it should occupy a similar role in science education.

Quantitative studies of progression in argumentation in science have shown that young students find tasks involving critique difficult (Osborne et al., 2016). However, Osborne et al. point out that their studies investigated the status quo, and they pondered the impact of giving students specific instruction and experience in critiquing evidence. Our findings suggest that such experience may well make a difference. Given the importance of this science capability for engaging meaningfully in the diverse socio-scientific issues besetting our world, these examples from primary-aged children provide some guidance as to what may be achieved in this area and how.

It should also be noted that during the unit, the students in Melissa's class also actively developed their understanding of what it means to 'gather and interpret data', and to 'engage with science'. Significantly, the study suggests that students' experience in data collection and interpretation contributed to their ability to critique data. Had the weather obliged, Globe at Night would have enabled students to gather and upload their own data. In the absence of this, Melissa's night-time photograph became a rich focal point for discussion about data reliability and its dependence on human interpretation. As Osborne (2014) points out "data do not wear their meaning on their sleeves" (p. 186). The findings described here and in the other cases support his suggestion that the ability to interpret data requires opportunities to also develop procedural understanding about how and why errors may come about.

The extent of students' capability development could be attributed, at least in part, to the level of challenge presented by the complexity of data interpretation required for the OCS. Similar outcomes were observed in the other cases, which also involved complex and challenging data interpretation tasks. Importantly, in each of these cases, the teachers deliberately created multiple opportunities for students to understand the processes of data collection and interpretation, and the students experienced for themselves the difficulties and 'messiness' of interpretation. The TLRI study as a whole highlights the importance of teachers understanding the intent of NZC for science and what the science capabilities entail. All four teachers' ability and inclination to recognise, design and support opportunities for capability development was an important component in maximising the potential offered by an OCS project. Clearly, Melissa's prior understanding of the intent of the science learning area within NZC and the science capabilities for citizenship significantly shaped students' opportunities for learning throughout the unit. For example, Melissa seamlessly used questions and ideas from the science capabilities teacher support website (Ministry of Education, n.d.). This suggests that these resources are an effective support tool for teachers, but teachers need to know to look for them and make them part of their practice.

The study also demonstrates the benefit of and need for targeted and consistent professional development for teachers to address the science for citizenship aspirations of NZC. Melissa's professional development in gaining her postgraduate diploma and participation in the Science Teaching and Leadership Programme contribute significantly to her classroom practice, and to the findings reported here. Like Melissa, each of the other participating teachers had previously engaged with the Science Teaching and Leadership Programme and understood the intent of science in NZC and the science capabilities. They were all committed to using the science capabilities as the basis for science programme planning. They also valued the professional learning and development opportunities inherent within the research project, which was collaborative and co-constructed as intended by the TLRI funding guidelines.

The research reported here and elsewhere shows the importance of appropriately scaffolding students' engagement with OCS projects (e.g., Brunvand & Bouwman, 2018; Chen & Cowie, 2013; Harr Ylizarde & Terrell Shockley, 2018; Schuttler et al., 2019; Zydney & Schaen, 2018). The study reported here highlights that school science experiences focusing on the science capabilities and integrating participation in OCS projects can contribute strongly to students' capability development. This case study also highlights the richness of opportunities for capability development that participation in an OCS can present if embedded in a science unit by a teacher who can recognise and develop its potential for student learning in science.

To support more teachers to explore the potential for OCS projects to enhance their own school science programmes, we collaborated with the New Zealand Science Learning Hub to develop a suite of resources that make planning decisions explicit (sciencelearn.org.nz/citizen-science). As with any educational innovation, wide-spread uptake will rely on teachers being exposed to the ideas and supported to engage with them, and ultimately for the teachers to experience success. Perhaps the world's recent experiences with COVID will galvanise new ways of thinking about and engaging with the purposes and processes of learning, including school science learning.

REFERENCES

Anderson, D. (2012). Teacher knowledges, classroom realities: Implementing sociocultural science in New Zealand Year 7 and 8 classrooms. Unpublished doctoral dissertation, Victoria University of Wellington, New Zealand.

Anderson, D., Luczac-Roesch, M., Doyle, C., Li, J., Glasson, B., Pierson, C., Christenson, D., Brieseman, C., Coton, M., & Boucher, M. (2020). Online citizen science in the classroom: Engaging with real science and STEM to develop capabilities for citizenship. In A. Fitzgerald, C. Haeusler, & L. Pfeiffer (Eds.), *STEM Education in Primary Classrooms: Unravelling Contemporary Approaches in Australia and New Zealand* (pp. 79-99). London: Routledge.
Brunvand, S., & Bouwman, J. (2018). A global perspective. Fifth graders practice data collection as they examine soil. *Science and Children*, 50-55.

Bull, A. (2015). *Capabilities for living and lifelong learning: What's science got to do with it?* Wellington, NZ: NZCER. Retrieved from https://www.nzcer.org.nz/system/files/Capabilities%20for%20living%20and%20lifelong%20learning%28v2%29.pdf

Chen, J., & Cowie, B. (2013). Developing "butterfly warriors": A case study of science for citizenship. *Research in Science Education*, *43*(6), 2153–2177. https://doi.org/10.1007/s11165-013-9349-y

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.

Ford, M. J., (2008). 'Grasp of practice' as a reasoning resource for inquiry and nature of science understanding. *Science & Education, 17*(2-3) 147-177.

Harr Ylizarde, N. & Terrell Shockley, E. (2018). Nurturing local-to-global thinking. *Science and Children*, 44-49.

Luczak-Roesch, M., Anderson, D., Glasson, B., Doyle, C., Li, Y., Pierson, C., & David, R. (2019). *Citizen scientists in the classroom: Investigating the role of online citizen science in primary school science education.* Retrieved from http://www.tlri.org.nz/sites/default/files/projects/Final%20Summary%20Report_Lukacz%20for%20web.pdf.

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

Ministry of Education. (2007). *The New Zealand curriculum*. Wellington, NZ: Learning Media.

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

NZCER. (n.d.). *Where will the wood float.* Retrieved from https://arbs.nzcer.org.nz/resources/where-will-wood-float

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education*, *25*(2), 177-196.

Osborne, J. F., Henderson, J. B., MacPherson, A., Szu, E., Wild, A., & Yao, S. Y. (2016). The development and validation of a learning progression for argumentation in science. *Journal of Research in Science Teaching*, *53*(6), 821-846.

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.

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.

Zydney, J., & Schaen, R. (2018). Tracking nature with technology. *Science and Children*, 38-43.