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Turning students into citizen scientists

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Highlights

- Schools can introduce vast numbers of citizens to participatory science.
- Students feel more engaged in their learning by participating in genuine scientific investigations where they are contributing to world knowledge.
- Citizen science projects offer opportunities for teacher professional development.
- Teachers have many opportunities to merge their curriculum with citizen science projects.
- Teachers need support in efficiently finding projects that fit their immediate classroom needs.

Introduction

Citizen science is growing in popularity, but most attention focuses on adult volunteers and their potential contribution to science and society. This disregards the millions of children studying science in school as they learn the skills of citizenship. Would hands-on involvement in real science projects simultaneously teach them about the scientific process and engage them with the world around them? Could these budding scientists contribute actual data and knowledge that adds value to science and society? Experience in education suggests that the answers to these questions are a resounding yes (see also Edwards et al.; Makuch & Aczel; Wyler & Haklay, all in this volume).

This chapter explores citizen science in schools. It highlights key learnings from the scientific literature, then explores a large teacher-developed citizen science project at the Leysin American School in Switzerland called LETS (Local Elevation Transect Survey). It includes the voices of students who participated in the LETS project. Finally, it shares ideas on how to integrate citizen science into teaching at schools. The conclusion discusses connections to the Ten Principles of Citizen Science.

How and why to embed citizen science into schools

Young people spend a large part of their lives in school. Some engage easily, whereas others struggle to see the 'relevance' of what they are studying. This can be especially true in the sciences, where concepts often feel remote from a young person's life. This is not helped by the fact that experiments they do in class and the data they collect are later thrown away. What if the data they collect could be preserved because it contributes to scientific knowledge, and maybe even helps to solve real problems?

Connecting citizen science and schools seems like a natural step. The promise of citizen science as an educational tool would appear to be a win-win game: teachers and students get authentic access to science in action, including scientists, scientific research questions, processes, data and data analysis, all of which promotes engagement with science and learning opportunities. Meanwhile, scientists get many enthusiastic volunteers (the students) along with team leaders and data quality filters (the teachers), while also expanding public awareness of their research topics and findings. A careful reading of the emerging scientific literature that explores citizen science projects in schools partly supports this hypothesis. It also highlights a few critical challenges, suggesting a 'trade-offs' model (Zoellick, Nelson & Schauffler 2012, p. 310).

Educational, motivational and transformative outcomes

What do students learn from participating in citizen science projects? There is considerably more literature on learning outcomes from general public participation in citizen science than there is from student participation. Research on public participation shows that learning outcomes are widespread but difficult to evaluate and highly differentiated. In environmental projects, Jordan, Ballard & Phillips (2012) identify the following learning goals from public participation: understanding ecology; understanding the science process; engagement with, and interest in, science and nature; motivation to participate; skill development in the scientific process and inquiry; environmental stewardship behaviours; and science and ecological identity. This typology has been extended to other scientific fields and to online citizen science projects with an alternative typology covering six levels of potential learning outcomes for individual participants: project-specific learning outcomes directly related to the tasks, concepts and mechanics of the project; disciplinary knowledge related to the topic of the project (for example, synthetic biology, philosophy or meteorology); scientific literacy; other knowledge and skills unrelated to the main topic of the project; personal development, including expanding interests and social networks; and identity change (Kloetzer et al. 2013; Jennett et al. 2017).

Citizen science in formal education, including primary schools, secondary schools and higher education, might be expected to bring similar individual learning outcomes. However, the material and social context of the classroom, as well as its social dynamics, are different from what can be observed in the general public. Specific research is needed to evaluate these learning outcomes but remains limited at the present time. The existing papers highlight three main things. First, citizen science projects indeed seem to teach disciplinary knowledge and increase scientific literacy (Zoellick, Nelson & Schauffler 2012), as well as positively alter attitudes towards science (Vitone et al. 2016). However, secondly, and most importantly, their value may go beyond these science-specific learning outcomes. The main outcomes of these projects may be motivational and transformative.

Participation in citizen science projects in college classrooms is reported to increase the sense of meaning of school learning and science courses. Considering Cell Spotting, a cell biology project, the authors write: 'besides helping students to consolidate and apply theoretical concepts included in the school curriculum, some other types of learning have been observed such as the feeling of playing a key role, which contributed to an increase in students' motivation' (Silva et al. 2016). In the classroom, teachers often struggle to find a balance between strict curriculum requirements and the desire to find new and interesting ways to engage and motivate students. Participation in the collection and analysis of real-world data is engaging for both students and teachers (Trautmann et al. 2012). By having actual value, citizen science imparts a sense of meaning in learning. Engagement with nature at a younger age may provide a means for engagement with science: 'Connecting young learners to the natural world through a citizen science approach provides a meaningful context for learning about science in the primary/middle age of schooling' (Paige, Hattam & Daniels 2015).

Thirdly, going beyond students' individual learning outcomes, citizen science projects may also benefit teachers and change the nature of schools themselves. Benefits to the educational process itself may be observed through increased engagement of the students and social relevance of the topics. Vallabh et al. (2016) report the following example: studying a river-monitoring project, they suggest that shifting the emphasis of the project from scientific testing to matters of concern for the local community serves as a driver of learning and change by emphasising situational motives and lifeworld contradictions.

The need for careful design and support for teachers

The existing literature also identifies critical challenges for the success of citizen science projects at school. The primary challenge is the balance between scientific and educational goals: 'Citizen science program leaders and scientists must clearly define the desired balance between learning goals and scientific goals. If broader learning goals are a priority, then that should be reflected in the activities of participants, and these goals should be stated explicitly'. (Jordan, Ballard & Phillips 2012, 307). The tasks offered should be consistent with learning goals, which are largely defined for teachers by the school curriculum (see also Makuch & Aczel in this volume). This requires the careful design of tasks offering both scientific interest and educational potential, which might be difficult, as 'the questions of interest to the scientists [are] not aligned with student learning outcomes specified in state educational standards' (Zoellick, Nelson & Schauffler 2012, 312). Keeping this balance between scientific goals and educational goals may therefore require third-party mediation (Houseal 2010, cited in Zoellick, Nelson & Schauffler 2012).

The second challenge is that of supporting teachers. Citizen science programmes need to offer relevant teaching material to ease the work of teachers in connecting them to school curriculum. However, 'simply offering project support materials, such as leaders' guides, to individual groups or teachers rarely leads to project adoption' (Bonney et al., 'Citizen Science', 2009, 980). Even more importantly, these programmes request and offer opportunities for teacher professional development. Reporting on the Acadia Learning Project, a collaboration with 11 schools, 20 teachers and thousands of students to investigate spatial variations in mercury in macroinvertebrates, Zoellick et al. (2012, 310) analyse the original impetus for working with teachers and students, which was 'a need to undertake long-term sampling and a desire to engage students in authentic scientific research', and noted that the project identified 'a need for teacher professional development'. As Zoellick et al. wrote, 'we had teachers and students who needed additional support to undertake basic scientific work but who valued the engagement with a real and complex project' (Zoellick et al. 2012, 312). This was solved with further professional training for teachers through regular online and occasional in-person access to scientists and summer institutes. Similarly, Paige et al. (2015) present two citizen science programmes developed as part of larger teacher professional development projects. In these cases, 'teachers realized the benefits for their students and their own professional learning' (Paige, Hattam & Daniels 2015, 11). This happened mostly through 'long term participation in small professional learning communities supported by university academics' (Paige et al. 2015, 12). Therefore, citizen science projects for classrooms should consider the needs of both teachers and students (Zoellick et al. 2012).

Support for teachers and careful design for educational purposes are important because otherwise it may be difficult for overworked teachers, constrained by busy curriculums, both to engage themselves in new, complex activities and to engage their students in activities with no clear connections to the required curriculum. Teachers often feel pressured for time and unsupported by administration when it comes to the extra effort needed to try a new form of teaching. Consequently, there are recurrent difficulties in recruiting classrooms into citizen science programmes.

Three models for embedding citizen science in schools

Three models for embedding citizen science in schools, which offer different resources to overcome the challenges identified above, are listed below.

Type 1: Adoption and adaptation of an existing programme
Type 2: Autonomous local development
Type 3: Local partnerships between scientists and teachers

These three models are summarised below before the chapter turns to present a case study of a type 2 project.

Type 1 projects take advantage of hundreds of school-friendly citizen science programmes worldwide, which may bring the difficulty of knowing which projects might fit a school's region or curriculum. For example, CITI-SENSE (www.citi-sense.eu) used high school students as citizen scientists in indoor air quality research. This international effort (across nine European cities) had the dual mission of gathering and analysing data, while also exploring how citizen science projects can best work with students and schools. In his report, SINTEF senior scientist Sverre Holøs stated that 'Results from the collaboration so far indicate that students and teachers are motivated to engage in these environmental studies, and able to perform studies of good quality' (Holøs 2016).

CITI-SENSE also found that while each city was successful at recruiting a school, considerable attention had to be paid to fitting the research into narrow windows of time during which the needs of the curriculum matched the needs of the science investigation. Schools also had concerns about privacy, misuse of data and how to navigate school policies on technology and internet access. CITI-SENSE therefore found that while recruiting schools was often successful, it requires significant time and effort.

Rather than actively recruit schools, it is more common for citizen science projects to simply make themselves available online for teachers to discover. Some projects have developed supportive resources, from teacher's guides to specific protocols and individual lesson plans. Perhaps the oldest and most widely used citizen science programme for schools is the GLOBE Program (www.globe.gov). Launched by NASA in 1995, GLOBE (for Global Learning and Observation to Benefit the Environment) is now used in over 100 countries and has over 100 million entries in its international database. Developed explicitly for schools, its teacher support materials are extensive and tied to American standards. A number of regional GLOBE offices have sprung up worldwide to serve local needs. Ironically, teachers in the GLOBE programme stated in personal communication that the sheer quantity of material that they offer is overwhelming for many time-strapped teachers.

Various hubs are also developing where teachers can learn about projects they might want to participate in. Some are highly regional, such as Tous Scientifiques (www.schweiz-forscht.ch), which promotes citizen science projects in Switzerland. For others, the earth is not large enough – Zooniverse (www.zooniverse.org) grew out of the popular Galaxy Zoo project, where anyone with a computer can help scientists to classify galaxies. The Zooniverse now offers photo-based identification and classification projects as wide-ranging as counting penguins in Antarctica and identifying endangered condors in California. Many of their projects offer supportive materials for teachers to use with their students.

The broadest citizen science project finder is SciStarter (www.scistarter.com), which offers over 1,600 projects. Users can narrow their searches by activity, location, whether projects are school-based and whether they offer teaching materials. SciStarter is currently biased towards the United States, which stems largely from its origins at Arizona State University's Center for Engagement and Training in Science and Society. However, according to the project's management, SciStarter also features an ever-increasing number of projects from outside the United States and is working to further develop its support for international education.

Type 2 projects are suited to especially motivated teachers who want to design their own projects relevant in their local environments. Key considerations in this context include, first, the choice of a research question, along with developing a connection to the scientific community. Next is the professional training of the teachers, if possible in a group where they can discuss how to guide students, as well as the ethical, scientific and practical issues of the research. Finally come the practical issues, including the choice of data collection and data analysis tools. Entering data on a website or app custom-built for someone else's project might not be useful. Several services now offer completely customisable data entry forms that are simple to use. MyObservatory (www.my-observatory.com), for example, allows users to create forms on their website that can be filled out in the field on a smartphone. The data goes to the MyObservatory site, which among other things offers the ability to create graphs and export the data in multiple formats, including universal comma-separated values (csv).

Type 3 projects involve deliberate partnering between scientists and educators. This type of project has been tested by Cornell Lab of Ornithology (CLO) over the last 20 years, where it has been extremely productive but requires careful planning and significant efforts from both teachers and researchers (Bonney et al., 'Citizen Science', 2009). It also requires interdisciplinary collaboration, in CLO's case between experts 'in education, population biology, conservation biology, information science, computational statistics, and program evaluation' (Bonney et al., 'Citizen Science', 2009). The co-construction of the research project facilitates connections to the curriculum, as in the BirdSleuth project, which was 'developed over three years with extensive input from more than 100 middle-school teachers across North America. Teachers helped to develop, pilot, and field test the curriculum so it covers subject matter (e.g., diversity, adaptation, and graphing skills) that teachers can easily integrate into their lessons' (Bonney et al., 'Citizen Science', 2009, 981). These partnerships require significant funding for both the teachers' and scientists' time to be able to reach a productive balance of scientific and educational goals.

In all cases, further research is needed to evaluate the outcomes and challenges of each of these types of citizen science projects in schools (see Kieslinger et al.; Richter et al., both in this volume). The next section presents a case study of a type 2 project.

LETS Study Leysin: An annual school-wide citizen science project

Presentation of the LETS Study

In 2014 the Leysin American School (LAS) in Switzerland decided to get involved in citizen science. Its teachers closely examined the local environment, considered how best to study it and developed a long-term research project appropriate to their locality and school. The school's individual experience has been broadened into a roadmap to starting a citizen science programme at school (see later section), which is intended to inspire other schools to develop their own long-term research projects.

The LETS Study Leysin project emerged from teachers' belief that getting kids outside and into the local forest would excite them about learning science; two years into the programme, they believe this more strongly than ever. Reaching across the curriculum to other departments, the study also engages the whole school, including nearly all the teachers. Following a strict set of data-collection protocols, students feel that they are contributing valuable information to experts who can use it to model the impact of global climate change on the forests of the Alps (the project, including its growing set of protocols, is described in depth at www.lets-study.ch.)

The town of Leysin is perched on a steep mountainside in Switzerland (figure 28.1). The town itself spans an altitude range from 1200 m to 1700 m. The hillside drops below the town to the valley floor at 450 m and rises above the town to a limestone peak at 2300 m, well above the local timberline. Thus, the obvious environmental characteristic of Leysin's geography is elevation. The main questions students are exploring through LETS are (1) How does altitude affect life? (2) How will climate change affect altitude distributions of species? The first question can be partially addressed during twice-annual days of research. The second question can only be addressed over a longer time period, but the

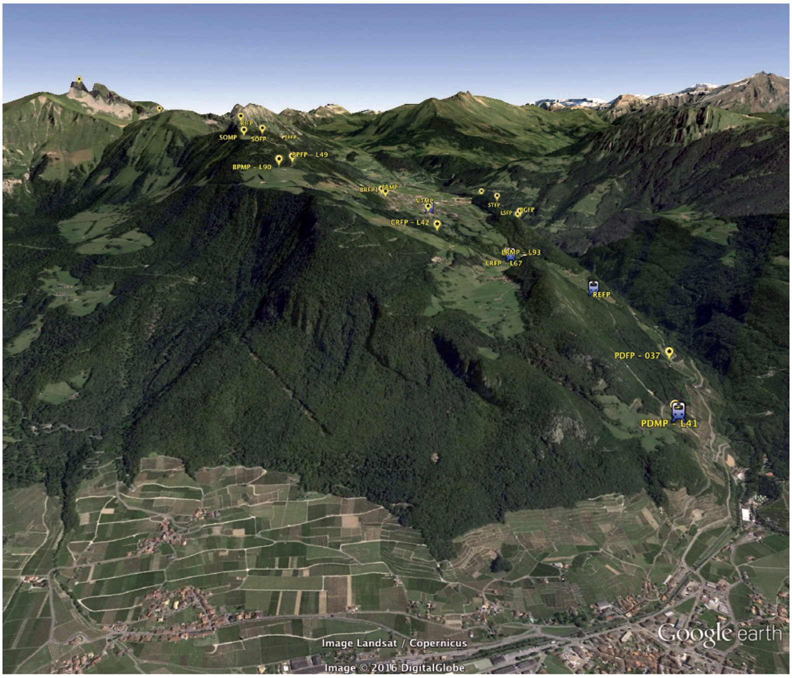

Fig. 28.1 The LETS Study Leysin plots studied by the Leysin American School span an elevation range from approximately 600 m to 2,300 m. Students visit the 30 m × 30 m plots that are not covered in snow twice per year, once in May and once in October. The plots are displayed in Google Earth.

research is expected to continue for decades, eventually turning into a serious longitudinal climate study, because it is being institutionalised in the school.

The transect itself was set up by LAS teachers in consultation with Dr. Christophe Randin, an ecologist from the nearby Université de Lausanne who specialises in the Swiss Pre-Alps, including Leysin (Randin et al. 2009). Teachers have so far established 14 fixed plots of 30 m by 30 m at altitudes from 600 m to 2,300 m (plus a dozen smaller meadow plots). These were chosen for their consistency of aspect, slope and forest cover, though there is diversity in forest type. Inside these plots, trees are identified, measured and mapped; species are inventoried with the iNaturalist app (which photographically records and geolocates species that can be corroborated via a social network of professional and amateur taxonomists); and students are given the opportunity to carry out their

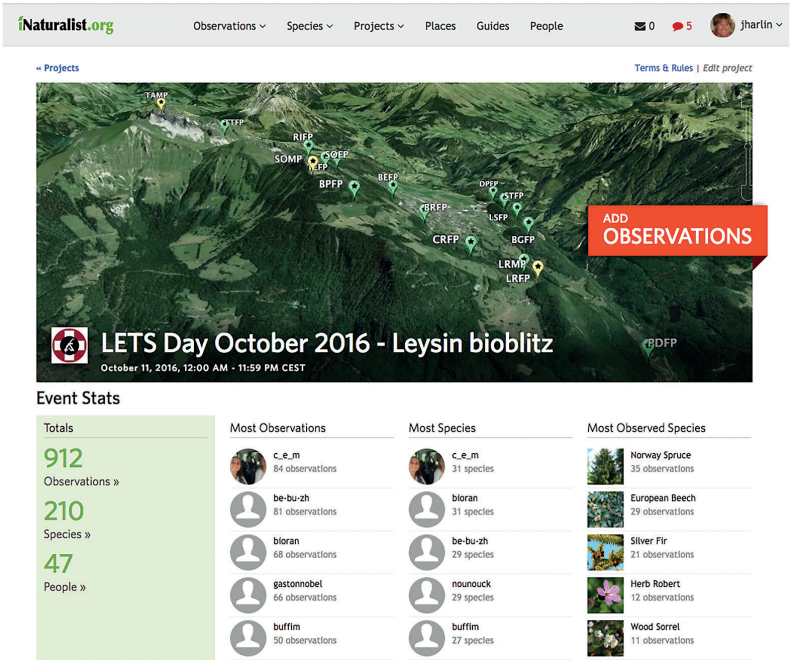

Fig. 28.2 LETS Days' happen twice a year: in October, about 130 7th- to 10th-graders fan out in groups of 10, one group to each site (with teachers for supervision); and in May, over 100 11th graders do the same as part of their International Baccalaureate (IB) Group 4 Day (Group 4 is a mandated co-operative science research in the IB programme).

own investigations. All accessible altitudes are investigated on the same day (snow-cover permitting).

Before heading out into the field, students write a journal entry recording their thoughts in response to the prompt, 'Describe the forests of Leysin'. In education terminology this is known as activating prior knowledge: asking students what they *think* they are going to see creates the mental space for them to absorb what they *actually* see. Laden with picks, tape measures, thermometers and cameras (among other tools), the groups then walk to their assigned plots. Once on location, students set up the boundaries of their study site then divide it into nine 10 m × 10 m subquadrats with string. Smaller teams measure, photograph and dig to collect data (figures 28.3 and 28.4).

During LETS Day in October 2016, LAS students were joined by about 50 students from the Université de Neuchâtel, along with a few

Fig. 28.3 The highest LETS plot with trees lies at 2,000 m on the Tour d'Aï. Here students have laid out strings to divide the 30 m × 30 m plot into nine subquadrats that are used for mapping the tree cover. (Source: John Harlin)

Fig. 28.4 The highest tree discovered by LAS students was found at 2,090 m on the Tour d'Aï during LETS Day 2015. (Source: John Harlin)

Fig. 28.5 Students practice tree measurements near campus at 1,390 m. During LETS Days the circumferences of all mature trees in most LETS plots are measured. (Source: John Harlin)

PhD candidates and their professor. Their mission was to conduct a more thorough BioBlitz (species inventory) of each plot by utilising iNaturalist and their skills with a taxonomy book. The school students finish each LETS Day by creating a quick poster based on their research.

Today we were scientists: Students recount their experiences during LETS Day

Overview of the experience: LETS Day report by the students

The following report has been compiled from students' own words as written in their afternoon reflection following LETS Day. The writing is lightly edited for continuity between the multiple authors.

> 'LETS Day was amazing. I was like a scientist. It was harder than I imagined, but an exciting experience. Learning about your community is very interesting.'

‘Over time this project will help us understand the changes that are happening to the forests around Leysin. From that information people will learn what to expect. Climate change is a big issue, and Leysin, being on top of a mountain, could be very affected by it. Our studies could help our town to prepare for and adapt to the coming changes.’

‘Citizen science is collecting data, analyzing it, and putting it out there for scientists to use. The data can be collected by anybody: students, teachers, workers, and many others. On LETS Day we collected data about trees, temperature, and other factors. It was quite interesting to feel like a specialist in tree identification. We entered the data into a document that can be looked at by scientists so they can observe climate change. This data will show differences when compared to data five or ten years later. Scientists can learn how the plants and animals start to move up the mountain because of climate change.’

‘We saved lots of time for these scientists. We did part of the work on the forest and now they have to do the other part.’

‘Here is what we did on LETS Day. First, we hiked for a long time. Many students were so tired. I like hiking, but I’m usually too lazy to walk anywhere, so I was happy to have this experience. I fell a lot of times, but it was okay because I learned how to hike in the forest.’

‘Our first job was to find the orange buttons [these mark the corners of each plot]. It was very difficult because there were so many trees. But we found all of them, then we put strings between the buttons so it became a square. Then we put strings again and it became like a grid with nine subquadrats. Then we divided into groups and measured and mapped the trees inside the subquadrats. The highlight of our exploration was putting the white strings on the hill.’

‘My group was in charge of “baby trees” and had to measure, take photos, and identify little trees. Others recorded the temperature every 30 minutes. Others wrote down the circumferences.’

‘It was kind of confusing to do all the things at first but then we got it. We made mistakes but we fixed them easily and carefully. The

> data we collected today was pretty accurate. Our group members were working together and we got everything done fast and with high quality.
>
> Then we ate our sandwiches under a huge tree with mud.'

> 'At the end of the day we put our measurements into the computer and it gave us statistics like average circumference. We input the data that we collect every year where everybody can see them.'

Highlights of the day

Interestingly, the highlights of the day vary greatly from one student to the other, even in the same group, highlighting that the real benefits of the project depend mostly on the subjective experience of the students. We identified three main types of reported highlights, which we call acting in nature, acting together (teamwork) and discovery.

Most LAS students come from large urban environments and their strongest impressions were simply of being outside in the forest, which was new to them. Some memorable quotes are included below.

> 'It is so cool to be in the forest. You get to run around, take pictures, and help other scientists. I will invite friends to come here and see what I just saw: a magical forest. Overall, it was a very wonderful and memorable experience, one that you have to have once in your life.'

> 'The highlight was eating and laughing with my group. We were all really cold and it was funny. I was really badly dressed but overall it was fun and interesting.'

> 'We went to the highest point of the mountain and I liked it very much. The view was amazing and in my opinion the exploration we did will help to find the difference in forest climate within the next years.'

> 'The highlight was being able to hold an earth worm in my hand for the first time. It was great!'

Some students remarked on how they felt empowered by teamwork and leadership:

> 'My favorite part of the day was having the opportunity to be a leader and help my community. Even if it was just a small part, small parts can have big jobs.'

> 'I enjoyed the leadership opportunity. I think it inspired me to try more leadership activities at LAS.'

> 'The team work made us close to each other. I really appreciated how teammates helped each other, all united in order to contribute to the ecosystem study.'

It suggests that various roles in teams may trigger different experiences and outcomes.

For others, the highlight was discovery, including how much they enjoyed field science:

> 'The highlight was meeting the university students and exploring the forest with them. Finding mushrooms and plants, observing them, and looking at differences.'

> 'I liked talking to the college students because that gave me knowledge on why climate change is a real issue that affects all of us directly.'

> 'How great of a school I am in to be able to physically study climate change and understand nature!'

> 'When I go to a university, I want to research forests.'

Roadmap to starting a citizen science programme at school

While LETS Study Leysin is an altitude transect and is thus not universally applicable, the teachers who invented it hope that the concept of transects will be picked up by other schools and adapted to their local environments. Transects are well established in ecological research and are thus a good concept to teach students. Even more important is the concept of long-term research, which is especially vital in climate studies. If schools can establish long-term observations of their local environment and collect the data, they can simultaneously teach basic biology and contribute to the advancement of scientific knowledge.

20 design claims for educational citizen science at school

Based on the literature and our experience in the LETS project, we would like to suggest some 20 design claims, which are organised into five categories: curriculum, resources, official support, teacher training and networking, and community. These design claims may orient overall project designs (in the broad sense of designing the tasks and the pedagogy of the project, but also its human, social and technical context).

1. **Curriculum**
   - 1.1. Tie project tasks to the curriculum, even at the textbook level.
   - 1.2. Create adaptable lesson plans and support teachers creating their own lesson plans.
   - 1.3. Design assessment tools that match local standards.
   - 1.4. Scaffolding: offer levels of advancement, both within projects and between projects.

2. **Resources**
   - 2.1. Plan resources for the teachers to support the extra effort required to engage in citizen science.
   - 2.2. Create and moderate a system for peer-to-peer sharing, discussing and learning.
   - 2.3. Provide flexible tools to create citizen science projects.
   - 2.4. Provide technical support from experts.

3. **Official support (support from school administration and education departments)**
   - 3.1. Integrate citizen science into the school philosophy and recognise citizen science as an educational tool in the school policy.
   - 3.2. Support citizen science training as professional development.
   - 3.3. Encourage flexibility at higher levels, including administration, education boards and curriculum developers.
   - 3.4. Provide official recognition for innovative pedagogy in science education.

4. **Teacher training and networking**
   - 4.1. Provide hands-on interactive training.
   - 4.2. Develop sources of fresh ideas for teachers who want to try something new each year.
   - 4.4. Develop library of how-to videos for using citizen science in schools.

4.5. Encourage peer-to-peer sharing, provide a user-friendly platform for the teachers to connect with each other, share experiences, get feedback and cooperatively develop lesson plans.
4.6. Develop a platform for teachers to connect with scientists who support school projects.

5. **Community (connection with local community)**
   5.1. Team up with museums and cultivate them as key allies.
   5.2. Develop public spaces (such as elegant websites) for presenting school projects.
   5.3. Build in opportunities for parental involvement.

A process to launch a first citizen science project at school

One of the great wonders of citizen science in schools is that there are so many possible directions to take. Ironically, this cornucopia of choice can be daunting for a teacher. How to choose the right project for one class or school? How to launch a first citizen science project in a specific school context? Based on the literature and experience, we suggest the following 10-step roadmap to help schools launch their own citizen science programmes.

Conclusion

Citizen science engages school students in many of the same ways that it is known to engage adults. Although literature on citizen science and schools is still emerging, there are some rich experiences to draw on. This chapter shows that such engagement adds significant value to formal education.

One challenge lies in merging the scientific value of projects with their educational value and, when necessary, prioritising goals. The Ten Principles of Citizen Science puts a strong emphasis on the scientific value of projects, including making the data publicly available. Science teachers, by contrast, have a clear professional priority to fulfil their educational mandate and have neither the tradition nor external motivation to achieve meaningful (e.g., accurate) data, nor to share their data outside the classroom. Without shared meaningful data, the projects have no direct scientific value. Thus, for citizen science to achieve its potential within formal education, it will need significant teamwork between practising scientists and practising educators. Such teamwork that benefits both professional

Box 28.1. 10 steps roadmap for launching a citizen science programme at school

1. Listen to your stakeholders. What questions excite the teachers and students? What are the talents of the people around you? Do you know any local scientists to discuss this with?
2. Consider your environment. What is available locally that you could research?
3. Hatch an idea. Think of engaging research topics. Are there any environmental or social hooks you can bring to your project? (e.g., water quality, garbage, air pollution, biodiversity changes, habitat conservation and so on.)
4. Build institutional support. Present the idea to administration departments and other stakeholders. Be sure to understand the details well enough to respond to concerns.
5. Cultivate connections to the scientific community. Universities, museums, science centres and other community groups often include community education in their missions. Use these human resources whenever possible – they add meaning to the project and help with student engagement. Ideally get them involved in steps 1–3.
6. Use good pedagogy. Be sure to tie your project to your curriculum. The project must support student learning at their level. Consider safety and privacy issues.
7. Follow the Ten Principles of Citizen Science as best you can, but recognise that your bottom line as a teacher is to educate, which loosely falls under number 9, 'participant experience and wider societal or policy impact'.
8. Launch your project. Expect something to go wrong.
9. Ask for feedback and adapt accordingly.
10. Think long term. The first time you try a new project might not yield great science, but student learning is at least as valuable as the data you gather. If you are doing worthwhile research, repeat it year after year, improving the results over time and gradually building a long-term study that offers real value to science as well as to education.

and citizen scientists (‘citizens’ in this context being students and teachers) is in fact one of the Ten Principles in its own right.

Another challenge is working within the difficult constraints faced by teachers, including time, training and curriculum. These challenges can be overcome by motivated educators with the help of developing technologies (apps, knowledge-sharing platforms) and a support structure built around integration of citizen science into the curriculum that includes a recognition of its value for young citizens and for science.