John Harlin, Leysin American School in Switzerland, jharlin@las.ch
Dr. Laure Kloetzer, Université de Neuchâtel, Switzerland
Dan Patton, Leysin American School in Switzerland
Chris Leonhard, Leysin American School in Switzerland
Students, Leysin American School in Switzerland

Turning Students Into Citizen Scientists

Highlights

- Schools can introduce vast numbers of future 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.

As citizen science grows in popularity, most of the attention focuses on adult volunteers and their potential contribution to science and society. But what about all 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 make them feel more engaged with the world they'll soon inherit? Could these budding scientists contribute actual data and knowledge that adds value to science and society? From our experience in education, the answers seem to be a resounding "yes".

This chapter explores citizen science in schools. We'll highlight key learnings from the scientific literature, then we'll explore the case study of a large teacher-developed citizen science project at the Leysin American School in Switzerland called LETS, for *Local Environmental Transect Survey*. We'll hear from students who've participated in the LETS project. We'll also examine how citizen science can be integrated into teaching, sharing some of the ideas generated by the session "Embedding Citizen Science Into Schools" held at the 2016 ECSA conference in Berlin.

1. How and why to embed citizen science into schools: what the scientific literature says

Young people spend a large part of their lives in school. Some engage easily, whereas others struggle to see the "relevance" of what they're studying. This can be especially true in the sciences, where concepts often feel remote from a young person's life. It doesn't help that the experiments that they do in class and the data they collect ends up in the garbage at the end of the semester. What if the data they collect could be preserved because it contributes to scientific knowledge, 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 a large number of enthusiastic volunteers (the students) and 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 et al., 2012, p.310).

1.1. Citizen science in schools may have educational, motivational and potentially 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. This research (from public participation) shows that learning outcomes are widespread, but difficult to evaluate and highly differentiated.

In environmental projects, Jordan et al. 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 behaviors; and science and ecological identity (Jordan, Ballard & Phillips, 2012). 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 one's interests and social network; and identity change (Kloetzer et al., 2013; Jennett et al., 2016).

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 very different from what can be observed in the general public. Specific research is needed to evaluate these learning outcomes, research that's still emerging. From the few existing papers we can learn two main things. First, citizen science projects seem to indeed teach disciplinary knowledge and increase scientific literacy (Zoellick et al., 2012), as well as positively alter attitudes toward science (Vitone et al., 2016). But 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. At a younger age, engagement with nature may provide 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 et al., 2015, p.11).

Thirdly, going beyond students' individual learning outcomes, one extended potential of citizen science projects may be for teachers, as will be developed in the next section, and to change the nature of schools themselves. For example, social engagement may be one outcome of such projects, as reported by Vallabh et al. (2016). Studying a river-monitoring project, the authors 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 emphasizing situational motives and lifeworld contradictions.

1.2. But it requires careful design, and support for teachers.

The literature also helps identify critical challenges for the success of citizen science projects at school.

The primary challenge is the balance between scientific and educational goals. As analyzed by Jordan, Ballard, and Phillips, "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, p.307). The tasks offered should be consistent with learning goals, which are largely defined for teachers by the school curriculum. This requires a careful design of tasks offering both a scientific interest and an education potential, which might be difficult, as "the questions of interest to the scientists were not aligned with student learning outcomes specified in state educational standards" (Zoellick et al, 2012, 312). Keeping this balance between scientific goals and educational goals may therefore require third party mediation (Houseal, 2010, cited in Zoellick et al., 2012).

The second challenge is that of supporting teachers. Citizen science programs need to offer relevant teaching material to ease the work of the teachers in connecting them to school curriculum. But "simply offering project support materials, such as leaders' guides, to individual groups or teachers rarely leads to project adoption" (Bonney et al., 2009, p.980). Even more importantly, these programs 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. analyze 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 that the project required "a need for teacher professional development". 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 for teachers. Similarly, Paige et al. present two citizen science programs developed as part of larger teacher professional development projects (Paige et al., 2015). In these cases, "teachers realized the benefits for their students and their own professional learning" (Paige et al., 2015, p.11). This happened mostly through "long term participation in small professional learning communities supported by university academics" (Paige et al., 2015, p.12). Therefore, citizen science projects for classrooms should consider the needs of both teachers and students (Zoellick et al., 2012).

If support for teachers and careful design for educational purposes are lacking, it may be very difficult for overworked teachers, constrained by overbusy curriculums, both to engage themselves into new complex activities and to engage their students in activities paralleling the curriculum with no clear connections. Teachers feel crunched for time and they often feel unsupported by administration for the extra effort needed for trying a new form of teaching[1]. The consequence is recurrent difficulties in recruiting classrooms into citizen science programs.

1.3. Three models for embedding citizen science in schools

As a conclusion, we would like to distinguish three models for embedding citizen science in schools, which offer different resources to overcome the challenges previously identified:

Type 1: Adoption and adaptation of an existing program
Type 2: Autonomous local development
Type 3: Partnering between scientists and teachers

[1] From ECSA 2016 Conference session on "embedding citizen science into schools", group discussions.

We will now briefly comment on these three models before presenting the case study of a type 2 project.

Type 1 projects take advantage of hundreds of school-friendly citizen science programs worldwide—which may bring trouble knowing which projects might fit a school's region or curriculum. For example, the program CITI-SENSE (www.citi-sense.eu) used high school students as citizen scientists in indoor air quality research. This international effort (nine cities across Europe) had the dual mission of gathering the data and analyzing it, while also exploring how citizen science projects can best work with students and schools. In his report to the ECSA conference, Holøs Sverre 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" (Sverre, 2016). They 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, about misuse of data, and about how to navigate school policies on technology and internet access. CITI-SENSE found that recruiting schools, while often successful, requires significant time and effort.

Rather than actively recruit schools, it's 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 program 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 their international database. Developed explicitly for schools, their 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, the very quantity of material that they offer is viewed as overwhelming by many time-strapped teachers who might otherwise engage[2].

Various hubs are 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 within Switzerland. For others, the earth isn't big enough. Zooniverse (www.zooniverse.org) grew out of its 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 toward the U.S., which stems largely from its origins at Arizona State University's Center for Engagement and Training in Science and Society. However, SciStarter also features an ever-increasing number of projects from outside the States and is working to further develop its support for international education[3].

Type 2 projects are suited to especially motivated teachers who want to design their own projects that suit their local environments. In that case, some issues need to be considered. First is the choice of a research question, along developing a connection to the relevant scientific community. Next is

[2] Personal communication with teachers in the GLOBE program.
[3] Personal communication with SciStarter management.

the professional training of the teachers, if possible in a group of teachers where they can discuss how to guide the 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 that's custom-built for someone else's project might not be useful. Several services are now available that offer completely customizable 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 into their site, which offers built-in cross-plot graphing among other things, but also allows full exporting in multiple formats including the universal csv.

Type 3 projects involve "deliberate partnering" between scientists and educators. They have been tested by Cornell Lab of Ornithology in the last 20 years. It is extremely productive, but requires careful planning and significant efforts from both teachers and researchers (Bonney et al., 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., 2009). The co-construction of the research project eases connections to curriculum, as in the BirdSleuth project, "developed over three years with extensive input from more than 100 middle-school teachers across North America. Because these teachers helped to develop, pilot, and field test the curriculum, it covers subject matter (e.g. diversity, adaptation, and graphing skills) that teachers can easily integrate into their lessons" (Bonney et al., p.981). But such partnerships require significant funding for both the teachers' and scientists' time 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. We will now turn our attention to a case study of a type 2 project.

2. LETS Study Leysin: An example of an annual school-wide citizen science project

INSERT FIGURE 1.1 HERE [Harlin_Fig.1.1_LETS plots Google Earth view 1.jpg]
Caption: Figure 1.1. The LETS Study Leysin plots studied by the Leysin American School span an elevation range from approximately 600m to 2300m. Students visit the 30m x 30m plots that are not covered in snow twice per year, once in May and once in October. LETS stands for Local Environmental Transect Survey. The plots are displayed in Google Earth.

In 2014, when the Leysin American School in Switzerland decided to dive into citizen science, teachers closely examined the local environment, considered how best to study it, and invented a long-term research project that makes sense for their locality and school. Their individual experience has been broadened into the roadmap to starting a citizen science program at school that concludes this chapter. Below is their particular case study, which they hope will inspire other schools to develop their own long-term research projects.

"LETS Study Leysin" is the mantra, where LETS stands for Local Environmental Transect Survey. Teachers believed that getting kids outside and into the local forest would excite them about learning science; two years into the program, they believe it more strongly than ever. By reaching across the curriculum to other departments, the study also engages the whole school, including nearly all the teachers. By following a strict set of data collection protocols, students feel that they're 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 village of Leysin is perched on a steep mountainside in Switzerland. The town itself spans an altitude range from 1200m to 1700m. The full hillside drops below town to the valley floor at 450m and rises above town to a limestone peak at 2300m, which is well above local timberline. Thus, for Leysin's geography, the obvious environmental transect is one of elevation. The biggest questions students are exploring in 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 each semi-annual day of research. The second question can only be addressed in due time. Because the LETS study is being institutionalized at the school, the research is expected to continue for decades, eventually turning it into a serious longitudinal climate study.

The transect itself was set up by LAS teachers in consultation with Dr. Christophe Randin, an ecologist from the nearby Université de Lausanne who specializes in the Swiss Pre-Alps, including Leysin (Randin, et al. 2008). Teachers have so-far established 14 fixed plots of 30m by 30m at altitudes from 600m to 2300m (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; and students are given the opportunity to carry out their own investigations. All accessible altitudes are investigated on the same day (snow-cover permitting).

These "LETS Days" happen twice per year. In October, about 130 7th-10th graders fan out in groups of 10, one group to each site (with teachers for supervision). In May, over 100 11th graders do the same as part of their International Baccalaureate "Group 4 Day" (Group 4 is mandated cooperative science research in the IB program).

Before heading out into the field, students write a journal entry where they jot their thoughts in response to the prompt, "Describe the forests of Leysin". In education lingo this is called "activating prior knowledge". By asking students what they think they are going to see, teachers are creating the mental spaces for them to file away what they will actually see.

Then it's time to head outside. Laden with picks, tape measures, thermometers, and cameras (among other tools), the groups walk to their assigned plots. Once on location, students immediately set up the boundaries of their study site with strings, then divide it into nine 10m x 10m subquadrats, also with strings. Smaller teams measure, photograph, and dig in order to collect their data.

During LETS Day in October 2016, LAS students were joined by about 50 students from the Université de Neuchâtel, along with a few PhD candidates and their professor. Their mission was a more thorough bioblitz (species inventory) of each plot by utilizing iNaturalist and their skills with a taxonomy book.

Dirty and tired, but with spirits high, students finish each LETS Day by creating a quick poster based on their research.

Box

Today We Were Scientists: Students recount their experiences during LETS Day

Note to editor: I have supplied several photos. Likely you can only use one, but this gives you choice.

INSERT FIGURE 1.2 HERE [Harlin_Fig.1.2_LETS Day Oct 2015_TopTree plot1.jpg]

Caption: Figure 1.2. The highest LETS plot with trees lies at 2000m on the Tour d'Aï. Here students have laid out strings to divide the 30m x 30m plot into nine subquadrats that are used for mapping the tree cover. Photo by John Harlin

INSERT FIGURE 1.3 HERE [Harlin_Fig.1.3_LETS_Highest Tree Tour d'Ai.jpg]

Caption: Figure 1.3. The highest tree discovered by Leysin American School students was found at 2090m on the Tour d'Aï during LETS Day 2015. Photo by John Harlin

INSERT FIGURE 1.4 HERE Harlin_Fig.1.4_LETS_tree measurement 1.JPG

Caption: Figure 1.4. Students practice tree measurements near campus at 1390m. During LETS Days the circumferences are measured on all mature trees in most LETS plots. Photo by John Harlin

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

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 include:

- 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!

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

- 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.

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.

End of Box

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.

3. Roadmap to Starting a Citizen Science Program 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?

Participants in the ECSA session “Embedding Citizen Science Into Schools” in Berlin identified a set of school-specific needs:

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

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

3. Support from administration
3.1. Integrate CS into the school philosophy and recognize CS as an educational tool in the school policy
3.2. Support CS training as professional development
3.3. Encourage flexibility at higher levels, including administration, education boards, and curriculum developers

4. Scaffolding
4.1. Offer levels of advancement, both within projects and between projects

5. Teacher training
5.1. Provide hands-on interactive training
5.2. Develop sources of fresh ideas for teachers who want to try something new each year
5.3. Maximize efficiency for teachers
5.4. Develop library of how-to videos for using CS in schools

6. Teacher networking
6.1. Develop a platform for teachers to connect with each other where they can share experiences, get feedback, and cooperatively develop lesson plans
6.2. Develop a platform for teachers to connect with scientists who support school projects
6.3. Team up with museums and cultivate them as key allies

7. Community
7.1. Develop public spaces (such as elegant websites) for presenting school projects
7.2. Build in opportunities for parental involvement

Based on their experience with developing LETS Study Leysin and on conversations with other teachers, Leysin American School faculty suggest the following 10-step roadmap to help schools in launching their own citizen science programs:

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, ….)
4. Build institutional support. Visit administration and other stakeholders with the idea. Be sure to understand the details well enough to respond to concerns.
5. Cultivate connections to the scientific community. Universities, museums, science centers, 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 10 Principles of Citizen Science as best you can, but recognize that your bottom line as a teacher is to educate, which loosely falls under #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’re 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.

4. Conclusion

Citizen science engages young school-based students in many of the same ways that it’s known to engage adults. Though the literature is emerging, experience is rich and the authors conclude that such engagement adds significant value to formal education. One challenge lies in merging the scientific value of projects with their educational value and, if necessary, prioritizing goals. Another challenge is working within the difficult constraints faced by teachers, including time, training, and curriculum. These challenges can be overcome by motivated educators.

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