

Citizen Science: Toward Transformative Learning

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Abstract

Citizen science can raise people's understanding of science while helping scientists conduct their research. Yet its potential for driving transformative learning is empirically underexplored. We present the results of a preliminary study with secondary school students engaged in a long-term citizen science project, from the formulation of the research questions to data analysis and discussion. Students learnt about and increased their interest in neuroscience. They were also able to reflect on the role of science for society and valued their involvement as active participants in the research. We discuss the opportunities and challenges of approaching citizen science for transformative learning.

Keywords

public engagement, science education, scientific citizenship, transformative learning, young people

Citizen engagement in scientific and technological projects, or so-called citizen science, has been widely seen as providing opportunities for education and communication to reduce the remaining distance between laypeople and

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science (Gray, Nicosia, & Jordan, 2012; Powell & Colin, 2008). Citizen science, however, has become an abstract concept subject to various interpretations, political standpoints, and aspirations that have been applied with mixed results. It is typically proposed as a win-win situation where citizens are offered the possibility to contribute to scientific research projects designed by professional researchers. Prevailing interpretations consider that through their participation, citizens increase their interest in scientific learning (Riesch & Potter, 2014) while contributing to the development of projects of scientists (Silvertown, 2009). By contrast, a less empirically explored and documented conceptualization of citizen science understands citizens as active agents capable of developing science that can potentially address their needs and concerns (Irwin, 1995). Such an approach is translated into activities intended to build capacities among citizens to have a meaningful voice in scientific practice while addressing the prevailing perception that scientific research and scientists are removed from societal concerns and needs (Hughes, 2001; Ruiz-Mallén & Escalas, 2012; Steinke et al., 2007). Under this lens, science challenges citizens and researchers alike to address daily complex problems and concerns through transdisciplinarity, reflexivity, and transformative learning (Jenkins, 1999).

Here, we present a preliminary study of the impacts of such a citizen science approach, where secondary school students and researchers cocreated a research project based on a question generated by the students. More specifically, we explore the potential of this approach to drive transformative learning, understood here as students' empowerment and increased capacities to think as autonomous learners of science within collaborative contexts (Irwin, 1995).

Setting the Project

This ongoing citizen science project starting in 2012 is based in a secondary school in Molins de Rei, Catalonia, Spain. It is a pilot project developed within the Nouveaux Commanditaires Sciences program (NCS), so it is important because the findings were to inform the methodology of future projects. The NCS program invites groups of citizens to request research projects that can answer open questions that address their particular concerns. In this respect, the tradition of scientists elaborating research questions is broken. To achieve this, a mediator guides citizens to articulate their questions. When one is identified that lacks an academic answer, specialized researchers are sought and invited to join the process. Together, researchers and citizens design a research project that is relevant for them and will be added to researchers' agenda. In this respect, researchers do not take the lead,

rather they coconstruct the research with citizens and collaborate to refine the associated questions, define, and perform the corresponding protocols. This process ultimately contributes to the political objective of enhancing citizens' legitimacy for and active involvement in scientific research. By so doing, it promotes democracy and empowers citizens with the tools of critical thinking. Compared to science shops (Stewart & Havelange, 1989), NCS can be identified as a travelling shop, reaching people who would never have imagined themselves devising a valid question for science. Indeed, the program sets out to include citizens from underprivileged or isolated communities who are far from the academic world (e.g., young people in poor suburbs, elders, and students in small villages).

The Catalan NCS program was initiated as a result of the spontaneous participation of three students from Molins secondary school in a science video contest.¹ In the video, the students asked the following question: "How do the colors of the walls at the school influence educational performance?" This emerged from their concern about the poor conditions of the school buildings and students' low attention and enthusiasm in classes. One of the competition judges was to become a mediator of the NCS program and invited the school to participate. The mediator then invited two neuroscientists from the Netherlands specialized in the study of attention behavior who would be appropriate to explore this issue with the students. While the researchers involved in the project were hesitant at the beginning, they are now advocates of this approach, convinced that it can produce socially relevant research and challenge their traditional approach to doing research (Bonnefond, Riboli-Sasco, & Sescousse, 2015).

Fifteen students and their teacher initially joined the project, and finally nine of them (seven girls and two boys between 15 and 16 years of age) voluntarily and regularly took part in a series of face-to-face and virtual meetings with the two neuroscientists and the mediator from 2012 to 2015. Through such collaboration, they prepared, coconstructed, and performed research projects that were further communicated to academic and nonacademic audiences (Figure 1). Students named the project "Investigating how Colors Influence Learning" (ICIL). The collaboration between students and scientists is still ongoing.

Exploring the Outcomes

One year after the ICIL project started, we organized the first focus group at the school. Students were asked to construct a time line to document their main learning events and interaction with scientists related to the project. A year later, we organized three focus groups to explore students' perceptions

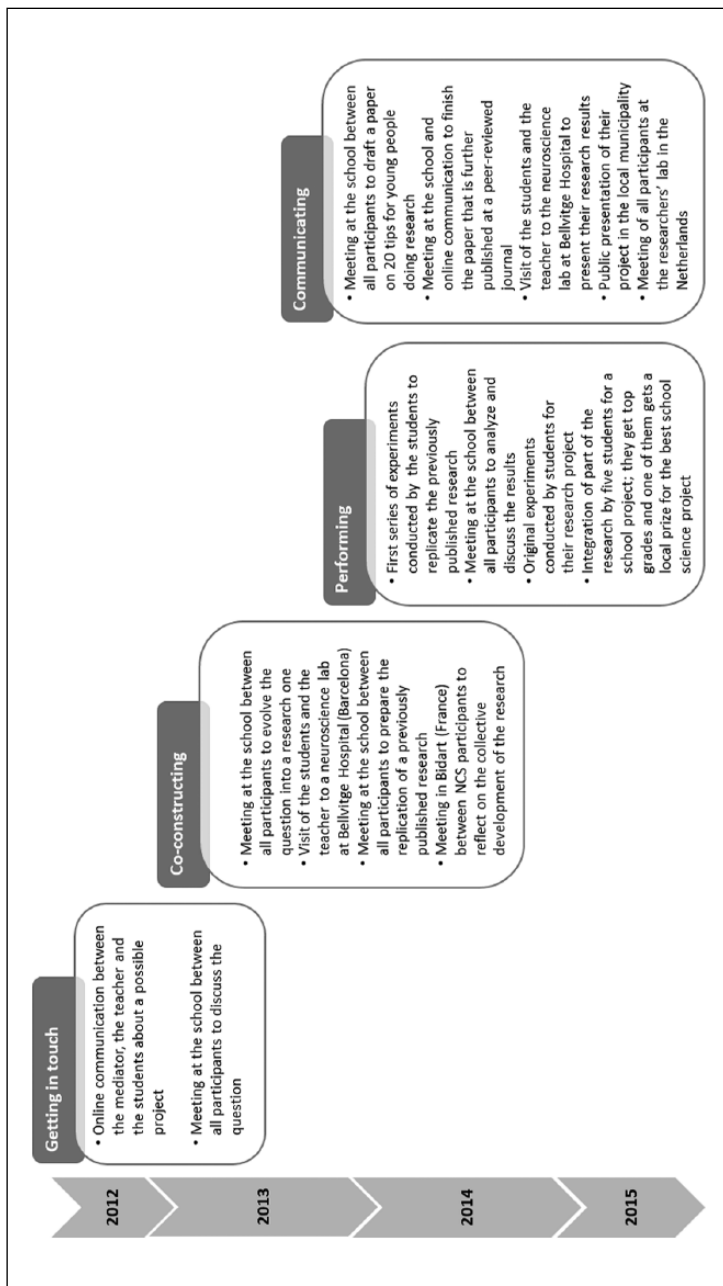


Figure 1. ICIL project activities and interaction among participants.
 Note. ICIL = Investigating how Colors Influence Learning.

and attitudes toward science and the development of skills such as critical thinking. We first used a Participatory Assessment Mural (Mural d'Avaluació Participativa in Catalan), a method based on a Likert-type scale that also includes qualitative data from a collective discussion (Güell, 2004). Students then participated in a role-playing game to explore their learning and empowerment with respect to scientific research and specifically with the project. Finally, students conducted interviews with each other to reflect about what they learned through this project.²

Scientific Learning and Social Skills Acquisition

Students' expectations for learning within the project were largely exceeded. They acquired basic concepts in neuroscience and research methodology; as one boy explained, "We learned about the scientific method and the purpose of a hypothesis, how to plan an experiment, how to obtain conclusions, how to interpret a sampling error, and how to determine sampling size."³ Students mentioned that many of these concepts were already covered in classes, but they understood their meaning only when ICIL scientists used real examples from their own research. Also, the preparation and test of their own experiment gave them the opportunity of "learning by doing" and improving their understanding of the research process. As one girl explained, "We did not consider some aspects that could make our results different than we expected." Interestingly, they also referred to new knowledge they acquired and would find useful at school, such as statistics, as well as nonscientific skills they would need in their professional life, such as the improvement of their proficiency in English and French and the acquisition of public speaking skills. They also learned to be patient and organized when working in groups, to avoid frustration when conducting research, and to work autonomously.

Raised Interest and Positive Attitudes and Perceptions of Science

Students' attitudes toward science education had changed slightly after 2 years participating in the project (Table 1). All agreed that meeting with scientists involved in the project was inspiring and crucial for raising their interest in science and research across different disciplines. Most of them mentioned that they were more motivated to study scientific or technological careers, although many were thinking about that possibility before the project. Two students were not interested in such careers but interested in conducting research in the humanities and social sciences.

Table 1. Percentages of students' answers to the MAP questions on their perceptions and attitudes towards science.

MAP sentences	Totally agree	Agree	Disagree	Totally disagree
I find science and scientific issues cool.	50	50	0	0
I like science even though it is often too difficult and frustrating.	25	25	37	13
I like to apply the scientific method because I learn about new issues.	13	87	0	0
I would prefer science to be certain.	0	25	13	61
After being involved in this project, I realize I can apply the scientific method to deal with daily problems.	0	37	50	13
After being involved in this project, I think research is more complex than I thought it was before.	13	0	50	37
After being involved in this project, I am now more motivated to study a scientific career.	61	13	13	13
After being involved in this project, I feel I could be politically active (i.e., contributing with my knowledge in social movements).	13	27	50	0

Note. MAP = Participatory Assessment Mural.

Overall, students' interest in science increased with their participation in the project. First, students came to realize that scientific research is a collective process. One explained, "I thought that science was theory and remembering concepts, but here I see that science also involves much discussion." Students also reflected that the stereotyped image they previously held of scientists had also changed; as one girl stated, "We did not expect scientists to be such kind and friendly people." Many attributed the enhancement of students' confidence in their participation to the trust and transparent relationship generated between researchers and students.

Surprisingly, half the students said they liked science because they perceived it is tricky and frustrating. As one of them explained, “Such complexity is a challenge that raises our interest and motivates us to try to understand science better.” Students discussed the issue of frustration in research. Reflecting on his own experience during the ICIL project, a boy said,

Our experiment was a turning point in the way we were learning to do science. It allowed us to understand that experiments often fail and to be aware that we needed to improve our experiment [because it failed]. We did not get frustrated but we learned that it is complicated.

Only two students agreed that they would prefer less uncertainty in the scientific practice in order to reduce the amount of time and resources invested in developing new and accurate medical knowledge and technology to improve social well-being. Others disagreed by emphasizing that scientific uncertainty did not equate to lack of accuracy: “When you get an answer you know how you have arrived at it.” They also argued that such uncertainty allowed for social improvements: “People have evolved due to uncertainty because they look for answers,” “Scientific uncertainty is what links science with philosophy.” At the end of the discussion, all acknowledged that science will necessarily be uncertain whether they liked it or not.

Empowerment Based on Self-Confidence and Collaboration

Students identified two main and interrelated empowering factors resulting from their participation in the ICIL project: self-confidence and collaboration. The experience had led a girl to recognize that “I am aware I can do it, I know where I am going, and I like working with others.” When considering the role-playing game, students referred explicitly to their improved sense of confidence. They mentioned that their parents were proud of them and typically told relatives and neighbors about the project: “They know we are doing something different.” In contrast, the students reported that their friends and teachers were rather aware but not interested in the project. They felt that such an attitude was due to a lack of understanding about the project; as one stated, “If they saw us working in this project their opinion would change.”

Students also mentioned their self-confidence and awareness of their abilities to collaborate, linking these with the evolution of their relationship with the scientists involved in the project. They expressed initial surprise that scientists started a direct relationship with them; as one girl recalled, “The first day of the project when they [scientists and mediator] came to the school I thought: they are wrong, they think that we are smarter than we actually are.”

Students perceived that scientists were interested in establishing a dialogue with them and could appreciate that scientists also learned from such interaction. As they mentioned, “They [scientists] like to help us and are inspired by us, listen and accept our ideas and take us seriously.” Although students identified themselves as active participants who were able to ask questions on their own and offer their opinions to scientists, they perceived scientists as holders of knowledge in contrast to themselves as nonexperts and learners. Still, such interaction was perceived as less top-down than other relationships they had with adults, including their teachers. In the words of one girl, they could speak with the scientists “as adults.”

Finally, students expressed different opinions regarding the impact of the ICIL project on their future political behavior. While they recognized that they were generally more interested in social debates as a result of their participation in the project, half the group felt they were still not ready to be actively involved in social movements (Table 1).

A Transformative Learning Experience

Students have enriched their understanding of the research practice. They gained firsthand experience with how people socialize in the academic community, its normativity, and its ambiguity. They now understand that frustration and complexity are part of the scientific process and are necessary to achieve accurate research results. Moreover, students have been able to design their own experiments, to analyze data, and to reflect on results by applying scientific knowledge that is meaningful in their own societal context. Students have also improved their self-confidence and collaboration among themselves and with scientists. Through such a situated, inquiry-based, and collaborative approach, we argue that the ICIL project has empowered students to behave as autonomous learners and to think critically about their actions and decisions regarding scientific practice. Most of these skills, values, and attitudes (e.g., critical thinking, individual responsibility, ability to work as part of a team) have been identified elsewhere as important for citizens to acquire in order to participate effectively not only in scientific research but also in their daily life activities (Blanco-López, España-Ramos, González-García, & Franco-Mariscal, 2015).

The learning experience developed through the ICIL project highlights three key elements that should be included in citizen science projects aiming to generate transformative learning processes.

First, as in this project, relationships and interactions were characterized as *transparent and trust building* and were elective, not imposed; scientists, students, and the teacher have participated voluntarily in all the stages of the

project. It was not advertised as a blueprint solution to foster students' interest in science; rather, the pros and cons of their involvement were clearly explained. For example, students were told it was possible they would not find an immediate answer to their research question. Transparency also engaged students and scientists in a collaborative process based on the establishment of a horizontal interaction. Such authenticity seems to have provided trust among ICIL participants.

Second, participants were engaged in a continuous *deliberative process* about the meaning and rationality of their actions, decisions, achievements, or limitations while conducting research. This seems to be crucial for having achieved their empowerment. For ICIL students, and citizens in general, in order to understand how facts and values from research are connected to their lives and to be able to make informed decisions, they need to become active agents in the knowledge-building process (Dietz, 2013). Reflexivity among ICIL students was promoted through discussions with scientists as well as during focus groups and other meetings without the scientists (including follow-up focus groups in this pilot study). We suggest that these processes allowed students to discover and develop their own skills and reinforce their motivation. Deliberation may also have the potential to change the frames of reference of students, countering some prior cultural, social, and political assumptions they held related to science and to themselves as knowledgeable actors in their society.

Third, and based on the philosophy of "slow science" (Alleva, 2006), the ICIL project was planned on a *long-term, flexible basis* (3–10 years), had *no performance targets*, but had some task deadlines. Such a long time frame facilitates the meshing of the agendas of both researchers, who often have a dense research schedule, and citizens, who typically pursue their own personal and professional lives. It may also allow transformative learning to take place. One cannot expect a full understanding of research values and methods with a few hours of lecture or even the best interactive workshops. Moreover, and contrary to what is required of most school projects, the absence of imposed research outcomes and deliverables does not mean a lack of results or low performance. The ICIL project demonstrates that students' engagement in research led to meaningful contributions that are usually restricted to professional, academic research, such as publishing a peer-reviewed scientific article (Andújar et al., 2015) and participating in a researchers' discussion at a departmental seminar (i.e., the neuroscience lab at the Bellvitge Hospital in Barcelona). We suggest that independently of whether students' motivation to conduct these activities may or may not result in a direct academic performance at school, they develop greater curiosity about the question posed, increased interest to contribute to find a socially relevant answer,

and, most important, the pleasure of sharing time with people eager to meet each other.

To conclude, the ICIL project has had impacts beyond responding to the request from society to researchers, or facilitating citizens to decide which questions should be addressed by scientists. It has shown that understanding how the answer is constructed is as important as the findings themselves. It is this deliberative research process that empowers: Citizens together with researchers can develop tools and skills, take decisions, collectively build knowledge, and critically analyze and communicate it. In the ICIL project, empowerment was demonstrated through students' reframing not only their attitudes and perceptions of science, but also changing how they think about themselves as valid, competent, and knowledgeable actors.

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Declaration of Conflicting Interests

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Notes

1. Science of the City (<http://www.scienceofthecity.net/>).
2. Further materials can be obtained from the authors.
3. All quotes have been translated from Catalan by the first author.

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