COMBINING SCIENCE EDUCATION WITH CITIZEN SCIENCE – EXPERIENCES FROM A RESEARCH INSTITUTE LED SCIENCE EDUCATION PROJECT

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Abstract Citizen science offers chances to gather observations and ideas and process data cost-efficiently while simultaneously increasing the outreach of the research. From the perspective of science education, it provides first-hand experiences about actual research work and personal contacts with researchers to its participants. Realizing this opportunity for mutual benefits, Finnish Meteorological Institute (FMI) has carried out a project combining citizen science with science education in co-operation with volunteering secondary schools. The project offered schools seven diverse research topics such as snow and birch pollen observations, development of weather service concepts and case studies in climate actions. Project work consisted of three parts: site visits, independent student work and reporting. Altogether 12 schools and over 200 students participated in the project during the fall and spring terms in the semester of 2014–2015. This paper describes the experiences from this first semester of the project. It is based on online questionnaires and interviews aimed at the participating students, teachers and researchers. Additional feedback was collected from an expert workshop. While actual research gains were modest, the satisfaction to the project was high within both the schools and FMI. Results encourage continuing this kind of cooperation and also studying further its educational impact.

1 Introduction

Learning by doing can be an effective way to complement traditional classroom based science education. At best, science education does not only improve the understanding of science and scientific skills of students but also gives a glimpse of science as a possible career choice in the future. In science, research and development, limited human resources are still often a crucial bottleneck hindering progress. Many processes require cognitive skills or creative effort that cannot yet be outsourced to computers. Addressing these issues can be combined in a way that supports each of them, benefiting students, teachers, researchers and the broader society at the same time. This has been the core idea and goal of the science education project coordinated by the Finnish Meteorological Institute (FMI) during the time period 2014–2015. This paper describes the project, labeled 5T (an acronym of the Finnish name, roughly translated as *Science Education in Secondary Schools by Doing Research with Researchers*) and its aims, structure and practices and explores its preliminary results based on surveys and interviews conducted in a self-assessment by FMI. The objective of this paper is to describe FMI's experiences and report the outcomes of this pioneering project for those interested in understanding, or further developing, the practices of combining science education and citizen science.

The background of the 5T project is the growing effort at FMI to connect the scientific research work to the use and benefit of the surrounding society. Improving the awareness of general public in topics such as weather risks and climate change is a recognized task of the institute, and activities such as visits from schools and open webinars have been arranged every now and then during the last few years. The special funding granted by the Finnish Ministry of Education and Culture made a more systematic, goal-oriented project possible.

2 Citizen science and science education

The aim of science education is to communicate and teach science to groups of people outside the traditional scientific or academic community. Naturally schools are directly involved in science education. As the understanding about the importance and mechanisms of science education has increased, more holistic views of including educating science within the school system have emerged on academic and professional arenas (McComas, Clough & Almazroa, 2006). Instead of concentrating on the specific knowledge obtained through science, the emphasis is on the understanding of the nature of science (NOS) in general (see e.g. Abd-El-Khalick, Bell & Lederman, 1997). The idea that the most important aspect of science is the scientific way to think and act, has prompted development of teaching methods other than the traditional classroom model. Inquiry-based learning (see e.g. Magnussen, Ishida & Itano, 2000) is one such methodology and championed widely by the European Union for example (European Commission, 2007). The idea of broader, more comprehensive science education has also heavily influenced the development of the so called Next Generation Science Standards in the U.S. schooling system (National Academy of Sciences, 2012).

Citizen science is bringing ordinary, volunteer citizens into actual research work. Although some form of citizen science can be traced as far in the history as science itself goes (Silvertown, 2009) the current trend of increasing interest towards involving volunteer citizens in research started more recently. A pioneer in the field has been Cornell Lab of Ornithology at the Cornell University that has experimented and developed models of citizen science since the 90’s (Trumbull, Bonney, Bascom & Cabral, 2000; Brossard, 2005; Bonney et al., 2009). A typical form of citizen science is training a large group of volunteers into making observations in a broad geographical area. Thus, most of the well-known and reported citizen science projects are related to biology and ecology, but also astronomy (Dickinson, Zuckerberg & Bonter, 2010). The potential of data collected by ordinary citizens has also been acknowledged in the field of atmospheric sciences (Muller et al., 2015).

Several authors have pointed out factors that either enable or drive the growing interest towards citizen science. First, internet and mobile technologies enable being in contact easily with thousands of citizen scientists (Cohn, 2008; Silvertown, 2009; Dickinson et al., 2010). Second, researchers have started to realize that the public can be a source for huge amount of free work resources that would be expensive or even impossible to employ otherwise; the potential price and scaling advantages are enormous. Third, citizen science can help to answer the demand for better outreach that is now often required by the funders. In Europe this outreach is emphasized in the Responsible Research and Innovation (RRI) discourse that is based on the idea that science should be done with and for society at large (European Commission, 2015).

Science education has been a central issue in many of the citizen science projects worldwide. As mentioned, it is often one of the motivations in establishing any citizen science projects. Some studies have also been conducted about the learning outcomes of these projects. They show increase in subject knowledge (Brossard, Lewenstein & Bonney, 2005) but mixed results on the impact to scientific thinking (Trumbull et al., 2000; Brossard et al., 2005). The citizen scientists in these studies have however been volunteers of all ages and for a large part people with interest and good background knowledge of the observed phenomena. Interestingly there is scarcely literature on directly involving schools in citizen science projects. Perhaps this is because students participating on a school course are not strictly speaking volunteers and thus not citizen scientists in the narrowest interpretation of the word. However there is evidence that school children even as young as third-graders can produce high quality observations (Delaney, Sperling, Adams & Leung, 2008).

5T thus differs in some aspects from the typical citizen science. The target participants were upper secondary school students specifically, and the co-operation is partly facilitated by teachers, which raises the educational expertise in the project compared to purely researcher driven approaches. Instead of mere observations, the participants were also tasked with some processing, analysis and creative work. The participant population was fairly small and measured in hundreds instead of thousands, although the idea has been to test practices for future larger scale implementation. Even with these differences, 5T is believed to be an interesting trial for a model of integrating science education and citizen science more closely.

3 Project goals, structure and topics

The main goal of the 5T project was to provide high-impact science education to secondary schools with the core idea of integrating student work and experiments with actual, on-going cutting-edge scientific research. Alongside this main goal the idea was to gain experience on the potential of citizen science for FMI's research, and to promote FMI as a research organization to the schools and students.

The project started with a preparatory phase in the spring of 2014, during which the first research task topics were gathered from researchers and the project was marketed within the school system and relevant organizations. The practical cooperation with first schools started in the fall term 2014, after which new schools were gradually included, and the practices and research tasks were adjusted according to feedback from students and teachers, and researcher availability. After the first full semester, a self-evaluation of the project was conducted using online questionnaires and interviews.

As discussed, the project work was in essence cooperation between researchers, teachers and students. The roles and responsibilities were the following:

- Researchers were responsible for designing the research tasks according to their own research needs. Their responsibilities included putting together instructions, briefing and being available for contact in case students or teachers needed additional aid during their work. Researchers were also tasked to explain what is the research problem being solved and what would be the benefit to advancement of science and society in general. In addition, researchers gave feedback on the scientific content of the student work.
- Teachers were responsible for tying the research topic tasks into school courses and supervising the student work during the research work phase. The teachers were also responsible in any grading or other school-related evaluation of the student work.
- Students were responsible for conducting the research tasks and reporting results as instructed by the researchers and teachers. Depending on the school and course, students had varying degrees of freedom to choose their research topics.

During the semester, the project work consisted of three activities: site visits, independent research work and final reporting. On site visits the school groups visited FMI head office. During the visits they were given introductive lectures about the institute, weather and climate science and research work in general as well as briefs about the research tasks. For each task, the responsible researcher described the background and wider context of the task and then described the work expected from the students. On some of the site visits demonstrative trial exercises were also conducted within the premises of the institute. In addition to the physical visits, the site visit lectures were streamed online for students and schools unable to participate physically to the visit. After the site visits, the students and teachers returned to their schools to conduct independent research work. During this phase the students were expected to complete the instructed tasks under the supervision of their teachers either during the class hours or as homework. The length of the independent work phase varied between few weeks to a whole semester depending on the course arrangements in the school. Group work was encouraged and was the most prevalent form of work. The students and teachers were instructed to be in contact with the responsible researchers for additional instructions and other aid, and in some cases also specific check-in virtual meetings were arranged. The forms of final reporting were varied and agreed independently with each school. Some student groups submitted only the raw observations or data while others compiled more comprehensive reports, depending on the requirements set by the teacher. This three-phase structure was run multiple times during the semester with some of the cooperation running partially parallel. Altogether six site visits were arranged.

During the school semester 2014–2015 altogether 12 schools and more than 200 pupils participated in the project. Of the schools 11 were upper secondary schools and one was a lower secondary school. Majority of the schools were from Uusimaa, the region nearby the research institute, but schools from other parts of the country were involved as well. One of the schools participated only via remote connection without visiting the institute. Although exact pupil records were not kept, as some pupils dropped in and out of the project as it went on, it was estimated that the share of girls of all the participating pupils was two thirds. In Finland, the share of girls in upper secondary students in physics is 37% and in biology 62% while the other natural sciences (chemistry, biology, and geography) and mathematics the share is in between physics and biology (Pääkkönen, 2013). It seems that girls were somewhat overrepresented among the project participants. This is aligned with the aims of 5T, which included encouraging greater participation of girls and raising interest and motivation for mathematics and science amongst all students.

The exact forms of participation varied among the schools. Some offered a special, volunteer project course, in which the students were free to choose their research topic and schedule within the limits of the course timetable. Some participated as part of voluntary, advanced courses and some as part of compulsory basic courses. The content of these two forms of courses in Finnish upper secondary schools are determined on general level by the Finnish National Board of Education. All of the courses were in natural sciences (physics, geography, biology, chemistry) and mathematics. The choices for research topics for individual students were limited based on the subject and form of the course depending on which of the topics the teacher saw as suitable for the course.

At FMI six researchers were involved in the project and were responsible for the seven research task topics, which are described in Table 1. For each topic, a written instruction was prepared. The detail of these instructions varied across the topics but most of them consisted of a brief background introduction, description of the task and practical guidance on reporting and sources for finding additional information. Exception to this was the seventh topic, Finnish climate data, which was only presented as an open ended possible task. No interested students or teachers were found for this topic.

Table 1. Research task topics within the 5T project in the 2014–2015 semester

Topic	Research task	Scientific motivation
Climate change	Gathering information of climate actions on municipal level	Gathering leads for detailed case studies
Snow depth	Tool-assisted snow depth measurement	Increasing the coverage of an observation database
Snow cover	Visual assessment of snow cover	Producing comparative observations to develop/validate satellite-based models
Aurora borealis and space weather	Processing of archived aurora borealis measurement data	Modifying old observations to be compatible with newer ones.
New weather services	Designing new uses for open weather and climate data	Testing the usability of an open data service, gathering ideas for further development
Pollen and phenology	Observing the progress of birch blossoming	Improving pollen dispersion models, gather new ideas for developing pollen warnings
Finnish climate data (no activities)	*Processing and analyzing existing climate data and adding own observations*	*Improving the climate database at FMI*

4 Evaluation and results

Feedback about the project was collected from researchers, students and teachers, and complemented with expert views from a workshop. Student opinions were studied with online questionnaires and group interviews. The online feedback surveys conducted after each site visit got altogether 52 responses from students, and the final survey for students in May 2015 got 30 responses, from the whole population of around 200 students. In the two group interviews six students were present. Based on the background information provided as part of the survey, the answers reflect the participating population in terms of gender distribution and school year, but no answers were received from students outside Uusimaa. None of the students from lower secondary school level responded the survey and all of the respondents had attended a site visit.

Most of the questions were in the form of a 5-point Likert scale, on which 1 represented the option “Completely disagree” and 5 represented “Completely agree”. Results from selected key questions are presented in Table 2. The results show that overall the students were quite satisfied in the project and felt that they learned about the nature of science. Increases in trust or interest towards science were lower than scores of the other statements, but the connection with actual research work seemed to clearly increase interest towards the tasks. Girls had on average higher scores for satisfaction and increase in trust, whereas boys had higher scores for the increase in interest towards science and research work.

Table 2. Selected mean scores from the final student questionnaire. (Scale used: 1 = Completely disagree ... 5 = Completely agree)

Statement	Mean
"If I now had the chance to do a traditional exercise instead of research task, I would choose the research task"	3.89
"I learned new insights about the nature of research work"	3.72
"Participation increased my trust towards scientific knowledge"	3.38
"Being aware that the tasks supported actual research increased my interest towards it."	4.03

While the primary function of the surveys conducted after site visits was to collect feedback about the practical arrangements, the students were also asked if they learned new insights about the nature of research work. Here too the score was quite high (mean 4.07). The students also considered site visits very useful (mean score of 4.10 for the statement "*Site visit was useful*").

In the final questionnaire, the students also had a chance to provide some free text answers. In one of the open questions the students were asked about what they thought they had learned. These descriptions of learning were categorized as describing learning research task specific content, FMI related information, nature of science or research work, general skills or other things. The distribution of these and examples of student input are presented in Table 3.

Table 3. Summary of feedback on learning experiences in the final student questionnaire by category.

Type of learning category	Number of times mentioned	Example
Research task specific content	11	*"[I learned ...] how to measure snow in the right way."*
Nature of science and research work	8	*"[I learned ...] about different research methods and writing a project paper."*
Other	3	*"[I learned ...] to pay more attention to weather."*
General skills	2	*"[I learned ...] group work, independent work and new kind of planning of work."*
FMI related information	1	*"[I learned ...] how much and diverse things FMI does."*

As Table 3 shows, most of the learning descriptions were related to the specific tasks but more general remarks of research work were made as well. The comments by students in the group interviews were similar, and students mentioned about learning terminology, new ways of working, proper citation practices and the broadness of activities at FMI.

Opinions of teachers were also studied with online questionnaires and group interviews. Eight teachers responded to the final feedback survey, which included both open and closed questions. All either completely agreed or somewhat agreed that the project was useful. All also had their expectations for the project met either completely or partially. The teachers were asked to provide open comments about what they thought their students had learned. In a slight contrast to the students, all but one teacher emphasized learning about the nature of science and research work. This aspect was also frequently mentioned, together with the interest to bring action and new type of content to courses, when teachers listed reasons to participate in the project with their students. Eight teachers also responded to the feedback survey after their site visits. Everyone either completely agreed or somewhat agreed that the site visit was useful and that they learned more about the nature of research.

Researcher opinions were studied with individual interviews. The researcher interviews concentrated on the motivation, expectations and gains of the project from their point of view. Content analysis was used to analyze and categorize the answers received in six researcher interviews (Tuomi & Sarajärvi, 2006). Three main reasons for participation emerged from the answers (Table 4). First, the project was seen as a way to communicate their research, as well as science and research work in general, to an interested and important audience. Some even saw this as a kind of duty of a researcher. Second, the project was seen as an opportunity to collect research data and new ideas. Thirdly the project and the cooperation with schools and students offered interesting and fun variation to normal daily work. The expectations reflected these motivations, but hopes for research data were diverse; some had high hopes, others were more reserved.

Table 4. Researchers' motivations to participate in the project supported by the example quotes from the interviews.

Reason for participation	Number of times mentioned	Examples
Communication aspect	4	*"Observations weren't the main reason for me to participate, but the will to cooperate with students and to tell them about science."* *"Part of the researcher's job is to tell different audiences about science and how research is done in practice. People often have a false image of what a researcher actually does."*
Research data collection	4	*"...in aurora borealis research we need to do reasonable amount of visual inspection especially when analyzing long historical time series. It is a task that a motivated student can easily do."* *"When I heard about the project, I though this could be an interesting way to get some input and ideas on how to use open data."*
Interesting variation to research work	3	*"One value in itself is that it is fun to get to cooperate with students and schools as it is something different than what we usually do here."*

The actual, direct research gains were described as modest. There were two main reasons for this. First and foremost was the small number of participating students or student groups for each individual task. The scarcity of data limits its scientific value. This is not a problem of spatial scale only, but also continuity; citizen science can contribute in producing long time series, but one semester – in practice meaning one period of snow and of birch blossoming –

is too short time to achieve this. Although researchers pointed out clear differences in the quality and detail of work between students and preparedness of different schools, the quality of work was in general considered sufficient. Despite the limited research benefits, the project was not considered to be a disappointment. The communicative reach was seen as a success, and the project helped to create contacts and practices for future cooperation with schools. Some new technical tools were also tested and put to use. The researchers did not experience the project to cause too much extra work, and saw no obstacles to scaling the project up to larger mass of students. Quite the opposite, their opinion was that the more students the better, because they could contribute more data. However coordination and management of the project did require significant work effort from the FMI in general. As individual researcher's extra effort was intendedly kept low by having a dedicated coordinator, these results should not be interpreted to indicate that citizen science projects are easy to set up and run.

One issue that was brought up in the interviews of all three groups was communication. For example researchers noticed that there seemed to be high threshold for individual students to directly contact researchers. Each group suggested some measures for increased interaction. One concrete suggestion was setting up or utilizing some kind of online platform, on which students could easily ask for guidance and get peer-support from other schools in their work.

In addition to the evaluative surveys and interviews, the 5T project and its preliminary results were discussed at a workshop with experts not affiliated with the project. The workshop consensus was that physical site visits are an important part of this kind of cooperation. When asked what would be the most important gain of including citizen science in school classes, the most popular answer was connecting course subject content into practical activity. Teaching scientific method and worldview and teaching new, advanced content were seen as less important. Workshop also discussed the obstacles preventing schools to participate in this kind of activities. The lack of time on courses and lack of necessary resources in the schools were brought up as the most important factors.

5 Discussion and conclusions

After reading and hearing the feedback from all participating groups – teachers, researchers and most importantly students – our project can be deemed a success. Perhaps most encouraging is the very positive overall tone of the feedback from the students. Very few of them were strongly negative towards participation, even though it was not voluntary for all.

The original assumption was that this kind of cooperation benefits both the schools and the research institute in their core activities, meaning that it would produce gains in both education and research. Based on our experiences, this is a somewhat strong claim. Especially the direct research gains were modest, mostly because of scale issues. Indirect results are more difficult to estimate and in any case it is perhaps more useful to think of 5T as a pilot for new practices than as an actual research effort. As such, it provided researchers opportunities to communicate their research, interact with society and practice methods and skills for wider citizen science. Thus in the long run such cooperation might yield positive impacts on research and advance knowledge generation within society. The education benefits for schools seem clearer, since both teachers and students expressed their satisfaction. In a resource and time constrained school world this seems an unlike outcome if they had not felt that the project was somehow useful from educational perspective. Still, it would be interesting to systematically study the learning impacts of this type of citizen science.

One goal of the project was also to educate students in the nature of science. Without a control group or actual tests of what has been learned, our conclusions are speculative, but still encouraging. If we assume that motivation and interest support learning, then the project seems to have been successful in improving science education. In contrast to this it is perhaps important to note that learning course specific content was not brought up much in the feedback. Still, in our workshop the experts were most interested in using citizen science to connect course subject content into practice, but this seems to be quite difficult. The research topics should be perfectly aligned with the course topics, which is in practice unlikely at least for the regulated basic courses. In this sense citizen science participation seems more suitable for teaching nature of science and general skills.

Future studies could be conducted to bring more light to these issues. If citizen science becomes more widespread practice in schools, a comparative, quantitative analysis of grades and choices of students participating and not-participating in such activities should be made. If and when large scale citizen science activities are designed, they should include a research component looking into their educational and research benefits.

Even with its limitations, the results indicate that bringing citizen science to school science education has significant potential. Hopefully the positive feedback inspires schools and research institutes – or teachers and researchers – to contact each other and collaborate in creating citizen science projects for the benefit of all. Active researchers and teachers are the prerequisite for this kind of co-operation, but it could be further encouraged by tasking a proper organization, such as a well-connected research institute, university or a co-operation party like LUMA Centre Finland, with the responsibility for facilitating citizen science in schools. Naturally this would require stable funding for continuity, which is especially important for the researchers. By its nature citizen science is very cost-efficient and is a chance for producing major impact with a modest investment, so supporting it is worth considering for policy-makers within the education system.

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