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Citizen Science: Schoolteachers' Motivation, Experiences, and Recommendations

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Abstract

Citizen science offers teachers a way to bring authentic scientific research into their classrooms by providing both teachers and their students with opportunities to contribute to authentic research. The potential of citizen science for science education has already been highlighted in various fields and by various stakeholders. More and more studies underpin this potential by providing evidence for the learning outcomes achieved through participation in citizen science projects. In formal education settings, teachers are the gatekeepers for teaching innovations and, hence, the ones who decide whether to engage students in citizen science. However, the expertise of teachers who have already participated in citizen science with their students has not been studied on a broad international level. Therefore, to investigate their experience and learn from their expertise, this study employed a concurrent triangulation design and invited teachers to participate in a survey ($N=56$) and an interview ($N=11$), independent of their country of residence, their school type, and their teaching subject. The results provide insights into teachers' motivation, the engagement techniques and types of activities they used, the challenges they faced, and their recommendations for implementing citizen science in formal education settings. The present findings have important implications for the design of professional development programmes and support networks for teachers in citizen science.

Keywords Citizen science · Teachers · Professional development · Science learning

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Introduction

On a generic level, citizen science (CS) describes projects that engage citizens in "different forms of participation in scientific knowledge production" (Haklay et al., 2020, p. 2) and can increase individuals' knowledge communities' collective intelligence as "they are commonly involved in data collection but can also be involved in initiating questions, designing projects, disseminating results, and interpreting data" (United Nations Environmental Programme [UNEP], 2019) . There have been many attempts to define the research approach that can involve citizens in various ways and during various stages of the scientific process (e.g. Bonney et al., 2009; Shirk et al., 2012; Wiggins & Crowston, 2014). Hecker et al. (2018) postulated that "CS activities' common, shared goal is to collect and analyse information that is scientifically valuable" and that this "distinguishes CS from areas such as experiential learning or environmental education" (p. 2). However, many CS projects pursue educational goals in addition to scientific or policy outcomes. Phillips et al. (2018) focused on North American CS projects and found that, in their sample, 92% of the projects listed at least one intended educational outcome on their Web sites. These intended educational outcomes included, for example, content knowledge, environmental stewardship, attitude/awareness, nature of science, interest in science, and communication and technology skills. Thus, CS activities can be considered as special learning opportunities that can be distinguished from other experiential learning or environmental education opportunities because they enable learners to participate in authentic scientific research. From this perspective, CS appears to be an interesting, somewhat novel format for informal and formal science education (Bonney et al., 2009; Kloetzer et al., 2021; National Academies of Sciences, Engineering, and Medicine 2018).

Although much has been written about the potential of CS for science education and several studies have been able to provide evidence for individual learning outcomes, one perspective has not been given much attention so far: What are teachers' experiences with CS? Teachers are education experts and their first-hand experience with CS should be investigated more and—even more importantly—should be heard and considered in the design of CS projects for formal education. Therefore, in this study, we aimed to explore the following questions with an international approach that is not restricted to a specific school type:

a) What motivates teachers to engage their students in CS activities?
b) What engagement techniques do teachers use when engaging students in CS activities?
c) What types of activities do teachers facilitate when they implement CS in their classrooms?
d) What challenges do teachers face when engaging students in CS and what are their recommendations to overcome those challenges?

Literature Review

Many synergies, but also tensions, have been identified between education and CS (Roche et al., 2020), regarding various aspects ranging from theoretical perspectives and communication aspects to practical issues in formal and informal education settings. Over the past decade, the body of evidence showing that CS activities achieve learning outcomes has grown.

Citizen Science Learning Outcomes in Students

The current state of knowledge on the learning outcomes that can be achieved through CS in formal settings is mainly based on studies that focused on an individual project or projects that were part of a specific funding programme. However, in recent years, a few review studies have assessed the success of CS in specific domains.

Aristeidou and Herodotou (2020) reviewed the literature on the learning outcomes achieved in online CS projects. They found 10 studies that empirically investigated learning outcomes in online CS projects and they pointed out that evidence has been found for increased topic-specific and general science knowledge in CS participants.

Another review study focused on the learning outcomes of biodiversity CS projects (Peter et al., 2019). The results are based on 14 peer-reviewed papers and show that, across various learning outcomes, the studies mainly reported positive results; only a few reported mixed results or did not find significant changes (e.g. Jordan et al., 2011 regarding self-efficacy, or Bela et al., 2016 regarding trust).

By providing opportunities to participate in authentic research, CS is said to have the potential to connect science learning with everyday life and potentially prepare the way for lifelong learning pathways (Jenkins, 2011; Makuch & Aczel, 2018). Some studies investigated the effects of CS beyond traditional learning outcomes and focused on the development of (environmental) science agency and STEM identity. Those studies reported evidence for agency development in informal and formal settings (Ballard et al, 2017; Harris & Ballard, 2021) as well as for the development of scientific citizenship (Wallace & Bodzin, 2017). Further, Maass et al. (2022) discuss how modelling real-life problems relevant to society, an activity that is essential in many CS projects (e.g. on Zooniverse), can connect science and citizenship education to address diversity and promote fundamental values in students.

Effects of Citizen Science Participation on Teachers

Although some studies focused on CS in formal education settings (e.g. Castagneyrol et al., 2020; Harris & Ballard, 2021; Kelemen-Finan et al., 2018; Wallace & Bodzin, 2017), most studies examined the effects on students and only very few focused on teachers.

Scheuch et al. (2018) were able to show that, when participating in CS with their students, "teachers managed to combine project and curriculum goals concerning environmental education" and successfully supported their students in appreciating biodiversity (p. 86). However, although the *nature of science* was an explicit focus of the CS activities, the teachers did not use opportunities to reflect on the research methods applied in the CS project with their students. Therefore, the goals regarding teacher behaviour pursued by project leaders are not always achieved during implementation in the classroom.

Rushton and Reiss (2019), however, were able to show that participating in authentic research projects with their students can lead to the development of a teacher scientist identity. Another study with 164 teachers who got involved in online citizen science activities while studying for their master's degree explored their views on citizen science in the classroom (Aristeidou et al., 2021). Findings indicate that they thought of citizen science as a novel way of involving students in doing real-world activities and acknowledged the importance of the online element in engaging students in different locations and of different ages.

Challenges and Opportunities—Teachers' Perspectives on Citizen Science

Teachers are gatekeepers for the implementation of CS into the classroom. Despite all the benefits, implementing CS may also provide challenges for teachers. CS may involve topics, methods, or tools that are new to teachers and students alike and might put teachers in a learner role, which can be unusual and challenging for teachers (Fazio & Karrow, 2015). How teachers cope seems to be affected by their confidence in their own scientific literacy (Jenkins, 2011) or by specific project-relevant skills (Kelemen-Finan & Dedova, 2014). Therefore, training for facilitators is recommended for CS project design (Lorke et al., 2019; Zoellick et al., 2012), similar to recommendations for professional development for the implementation of new teaching practices in general (Mandrikas et al., 2021) and the establishment of collegial networks for teachers working towards a similar goal (Pop et al., 2010). These recommendations are echoed in a book chapter co-authored by expert classroom teachers in CS from the Leysin American School in Switzerland. In the chapter, they additionally call for more support for teachers "in efficiently finding projects that fit their immediate classroom needs" (Harlin et al., 2018, p. 410).

Therefore, against the background of these challenges, the question arises as to what motivates teachers to engage their students in CS. Several studies have investigated volunteer motivation in CS (e.g. Raddick et al, 2013; Rotman et al, 2014) and Robinson et al. (2021) recently clustered the motives into the following categories: (i) Values, (ii) Personal development, (iii) Career and recognition, (iv) Social, and (v) Recreation.

The studies on teachers' motivation to engage in CS, however, are sparse and tend to focus on a particular group of teachers, for example, primary school teachers in New Zealand (Doyle et al., 2017) or middle school teachers in the US (Bracey, 2018). Teachers can be motivated to participate in CS activities with their students by the desire to involve their students in authentic scientific research (Bracey, 2018; Doyle et al., 2017). Teachers act as proxies, aiming to achieve outcomes for their students through participation in CS. These aims can include, for example, contributing to their communities (Bracey, 2018), providing learning opportunities to support students' knowledge and skills development through practical experience (Doyle et al., 2017), or developing agency in students (Bracey, 2018).

Methodology

Participants and Recruitment

We recruited primary and secondary school teachers of any discipline who had already engaged their classrooms in CS activities. To recruit participants—on a volunteer base—we forwarded our invitation to social network communities in the field of CS, such as those of the *European Citizen Science Association* and the *Citizen Science Association*, and to national CS platforms and centres in Europe such as *Bürger schaffen Wissen* (Germany, and the *GLOBE* program (Global Learning and Observations to Benefit the Environment). In addition, we used teacher social media channels and groups on Twitter and Facebook (e.g. #twitterlehrerzimmer, #edchat) in English, German, Greek, and Spanish, as these are the languages of the project partners and collaborators. We used the snowball sampling method to reach teachers with the required experience (Everitt & Skrondal, 2010). Ethical approval was obtained from the Author A's university ethics committee. Participation in the study was voluntary. Teachers were asked to fill in the survey and could opt to be contacted to participate in the interview study. The data set was finalised by anonymising the responses on the 30th of June 2020, prior to the data analysis.

Study Design

This study employed a concurrent triangulation design (Creswell et al., 2003). Participants were invited to complete an online survey and to take part in semi-structured interviews. The five core research topics (motivation, engagement techniques, activities, challenges, and recommendations) were identified based on previous workshops with teachers who had a similar experience to that of the teachers who participated in the study. During the study, an interactive approach was used, in which findings from the survey responses influenced the focus of the interview data that were collected from the particular participants. Survey and interview data were first analysed separately and then merged into one overall interpretation, relating the survey results to the interview findings. The interview data were used to explain the survey results, and vice versa. Therefore, the survey results were converged with the interview findings to help us better understand the experiences of schoolteachers who had engaged their classrooms in CS activities. Accordingly, we integrated the survey and interview findings for each topic, to report the results.

Survey

The online survey ran between the 1st of December 2019 and the 3rd of March 2020. The focus of the survey was to gather quantifiable data about the experiences of teachers who had engaged in CS activities with their students. Prior to inviting participants, we piloted the English version of the survey instrument with two teachers to examine the clarity of questions which resulted in a few minor changes in writing style. The final survey questions were then translated into German, Greek, and Spanish.

To gain information about the teachers' background, the survey included questions related to their gender, age, location, teaching subject, class grade, and previous experience with CS projects. Information about main themes, namely the teachers' motivation, engagement techniques, activities, challenges, and recommendations regarding CS was collected via open-ended short text questions and closed-ended questions with an "other" response option where more information could be provided by the respondents. The survey can be found in Supplementary File A and the responses were translated into English.

Inductive content analysis (Morgan, 1993) was used for the analysis of the open-ended survey responses and responses to the "other" option. As a method, content analysis is content-sensitive and flexible (Krippendorff, 1980) and can be used with either qualitative or quantitative data (Elo & Kyngäs, 2008). For this task, the inductive approach (moving from the specific to the general) was followed as there is little existing knowledge about classroom-based citizen science. Content analysis takes place in three main phases: preparation, organising and reporting (Elo & Kyngäs, 2008). For the "preparation" phase, the authors selected the unit of analysis—a survey response, which could be formed by one or more sentences. In the "organising" phase, the authors organised the data in an excel sheet per survey question and performed open coding—categories were freely generated to describe each unit of analysis. The categories were then compared and grouped under higher-order headings (using content-characteristic words) to reduce the number of categories by merging those that are similar and form answers to our research questions. To improve the reliability of the analysis, an initial codebook for the survey analysis was produced by Author A and, in a second step, was refined into a more concise coding framework by merging individual codes into categories when appropriate. Applying the refined survey codebook, Author C conducted the final coding to complete the investigator triangulation. The codebook(s) with codes, descriptions and examples of what each code denotes for the five open-ended survey questions can be found in Supplementary File B. The identified content analysis categories were used alongside the closed-ended response findings in the reporting of the findings to describe the answer to each survey question. Percentages of responses and graphs were used to visualise the statistical data captured from the closed-ended and quantified open-ended responses. Content analysis in this work allowed making replicable and valid references from data to provide a representation of facts and a practical guide in relation to our research questions and the experience of teachers' when engaging in classroom-based citizen science activities.

Semi-structured Interviews

The interview protocol was created and piloted prior to the start of the study. The interview involved questions related to the main research question components (motivation, engagement techniques, activities, challenges, and recommendations) (see Supplementary File A). Interviews were used not only to capture rich data but also to further explain some of the survey responses. To identify the experiences of teachers who had involved their students in CS activities, deductive and inductive thematic analysis approaches were followed to thematically analyse the data (Azungah, 2018; Braun & Clarke, 2006; Miles & Huberman, 1994). The interviews (conducted in English) were recorded, transcribed and then analysed.

The main themes were preconstructed and reflected the research question components (motivation, engagement techniques, activities, challenges, and recommendations). Prior to the interview analysis, the two authors had initial discussions including ideas on the codes based on (a) Author A's experience with conducting the interviews and (b) reading articles related to the preconstructed themes (i.e. motivations in CS). These initial discussions contributed to achieving a shared understanding of the interview content and developing possible codes for the preconstructed themes. Codes were identified by Author C after analysing a small number of transcripts; they were then verified and modified where necessary by Author A to ensure inter-rater reliability (IRR). The IRR was calculated according to Miles and Huberman (1994) by dividing the number of times both coders agreed by the total number of times coding was possible; the interrater percentage agreement reached 85%, which is considered highly acceptable. The main disagreements were on the motivations for engaging in CS activities, and the type of activities undertaken while participating in the CS projects. The two coders resolved disagreements by merging codes with similar meanings into a single code so that the developed codes are coherent (Braun et al., 2016). Table 1 presents the themes and codes. The detailed codebook with the 17 codes, a brief description and an example of what each code denotes can be found in Supplementary File C. In the results section, we provide detailed results for each theme, and we also provide quotes from the interviews. Each quote is followed by the identified theme and code, and participant identifiers and characteristics in the following form: participant's identifier, age group, gender, and school level. For example, challenges (theme), permissions (code), T20 (identifier), 35–44 (age group), female (gender), primary school teacher (school level).

Table 1 Identified themes and codes

Themes	Codes
Motivation	Professional development opportunity
	Interest in topic of the CS project
	Students' generic skills development
	Students' science learning
Engagement techniques	Teaching approaches
	Students' interactions with experts
	Parental involvement
Activities	CS activities
	Additional activities related to the CS activity
	Collaborative activities
Challenges	Student motivation
	Teacher motivation
	Resources
	Permissions
Recommendations	Collaboration and support
	Value and enjoyment of science
	Dissemination of findings

Table 2 Participants' demographics

Demographics	Survey Respondents		Interviewees	
	n	%	*n*	%
Gender				
Female	32	57	7	64
Male	24	43	4	36
All	56	100	11	100
Age				
25–34	5	9	1	9
35–44	37	66	8	73
45–54	9	16	2	18
55–64	5	9	0	0
All	56	100	11	100

Participants

The final number of participants was 56 for the survey and 11 for the interview; the interviewees were survey respondents who agreed to take part in the interview via the survey. Our survey included 32 female (57%) and 24 male (43%) participants. The majority of the teachers who took part in the survey were 35–44 years old (66%), followed by respondents aged 45–54 years old (16%); 9%

of the respondents were aged between 25 and 34 and a further 9% between 55 and 64. Table 2 shows the main demographics of the survey participants and the interviewees (who completed the survey).

Based on the survey data, teachers from 15 different countries in Europe, North America, and South America participated in this study. Most survey respondents (55%) worked in lower secondary education, 29% worked in primary education, and 16% worked in upper secondary education. Biology teachers made up the largest proportion of our survey respondents (55%), followed by generalist teachers (20%), teachers of physics (18%), and teachers of technology (7%). Only 16% were new to CS.

Results

Motivation

Survey Results

The content analysis of the open-ended survey responses showed that teachers were motivated to engage their students in CS activities for one (54%) or more reasons (36%). The main motivation reported by 43% of the survey respondents was related to students' learning (including agency) (Fig. 1). The learning-related motivation was focusing on developing students' content knowledge on a particular subject, their overall science learning and skills and their agency. Important other types of motivation involved novelty in teaching activities (39%), the topic of the CS activity (27%) and engagement in and contribution to research and authentic science (25%). Some respondents indicated their own professional development (13%) and a small proportion (7%) reported motivation related to the location or the opportunity to use mobile devices.

Interview Results

Based on the interview data, the following codes for the topic of motivation were identified (see also Table 1): professional development opportunity, interest in topic of the CS project, students' generic skills development, and students' science learning.

The interview data revealed that teachers considered their engagement in CS activities a *professional development opportunity* and a way to interact with scientists and researchers in universities and science centres. CS activities were seen as a means of expanding their own knowledge and establishing connections with experts on a topic. Teachers also expressed their enthusiasm about their collaboration with scientists, as the following quote shows:

"We had, I think, four days [for the project collaboration]. That was a day for planning and then three reflection days, sort of, during and after the unit [a particular physics unit about light and light pollution]. So, that was when I was actually in

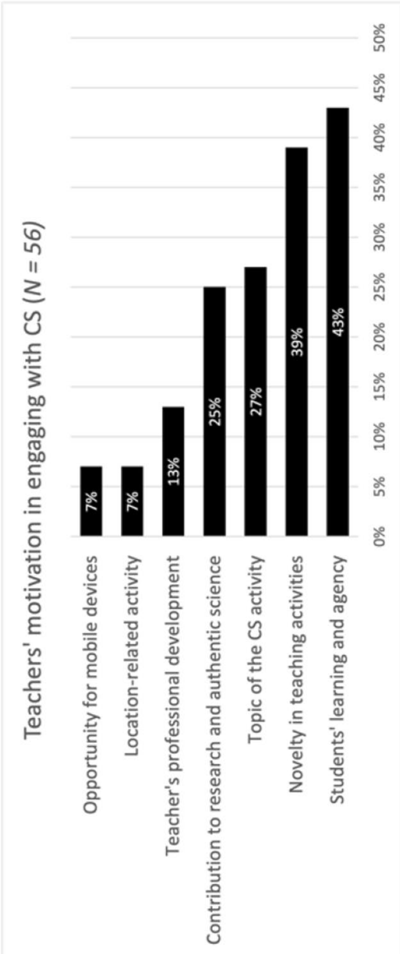

Fig. 1 Teachers' motivation in engaging with CS activities

a room with the researchers, actually working on the project and discussing our findings, and reflection." (T20, 35–44, female, primary school teacher).

Contrary to the survey findings, the *development of students' generic skills* was a frequently mentioned topic. These skills included science-related skills and personal skills such as decision-making and group work:

"And then they'll [the students] be the ones who archive that, they'll be the ones that then decide amongst each other which ones to look at in detail and try and work out the sequencing relationship between those samples. […] so it's all about them making the decisions amongst themselves in that larger collaboration." (Motivation, students' generic skills development, T18, 35–44, male, secondary science teacher).

Overall Interpretation

Teachers' motivations for joining CS activities with their classrooms ranged from personal motivations, such as their professional development, development of connections with scientists, and interest in a particular topic, to altruistic motivations, involving contributions to science and research, and finally to student-related motivations. Regarding the latter, CS activities were expected to improve students' learning, skills and agency, and retain their engagement with different and novel teaching practices that relate to their location and real science.

Engagement Techniques

Survey Results

The engagement techniques mentioned in the survey responses that were used by teachers to motivate students to participate in CS activities included interest in the topic (41%), teaching approach (25%), collaboration and events (20%), use of technology (14%), outdoor activities (14%), and helping scientists (14%) (Fig. 2).

Interview Results

Teaching approaches, students' interactions with experts, and parental involvement were the main codes identified as engagement techniques in the interviews.

The qualitative data indicate the different *teaching approaches* teachers implemented to make the CS activities attractive to their students. Some of these approaches focused on particular learning approaches (e.g. inquiry learning), and linking activities with students' everyday life, for example:

"I think it is just a different way to do science, to help the students to be more engaged in science. Talk to them about real problems they can see in their everyday life, so it is not about the idea, it is just really a different way to teach science in the classroom." (Engagement techniques, teaching approaches, T22, 35–44, female, secondary science teacher).

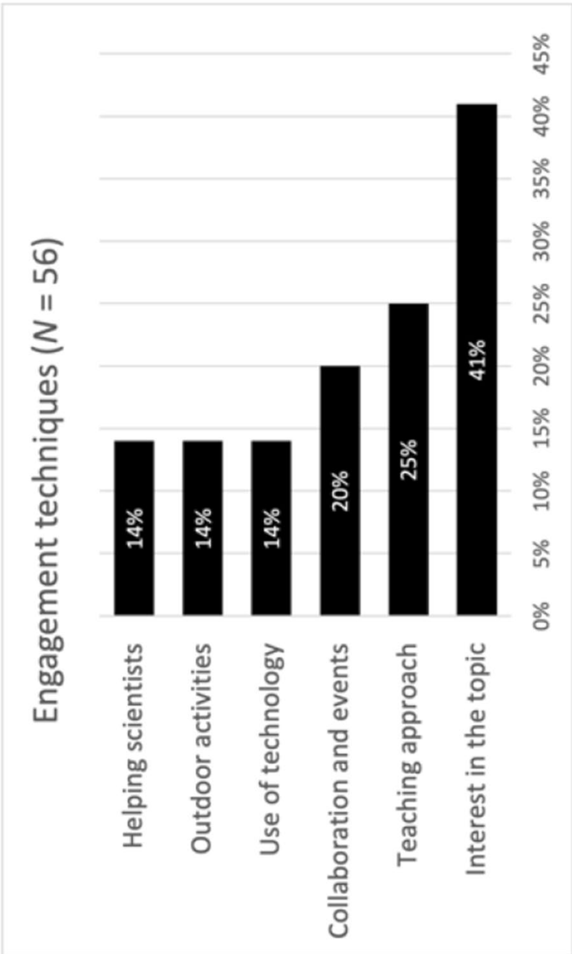

Fig. 2 Engagement techniques used by teachers to motivate students in the CS activities

Furthermore, teachers explained that they adapted their engagement techniques according to students' characteristics such as age. Teachers implemented CS across varying age groups and introduced different roles for younger and older students and made them work in teams:

"So maybe teaming up some of the older kids and the younger ones, so that as they're counting birds in different areas, the older ones might be writing down the data and making graphs and things, whereas the younger ones just go, 'Look, there's a bird, I think it's a tui.'" (Engagement techniques, teaching approaches, T19, 35–44, male, deputy principal and secondary science teacher).

Overall Interpretation

Engagement techniques used by teachers to engage students in CS activities involve intrinsic and extrinsic motivations. Teachers expected that students would be moved by topics relevant to their interests and the fact that they are contributing to real science. However, they also tried to increase this interest, by making the CS activities more attractive. Changing their regular teaching approaches, using technology, involving parents, highlighting potential interactions with scientists, and attending outdoors and extracurricular activities (such as events and field trips) were methods teachers used to enhance their students' interest in the activities.

Activities

Survey Results

According to our survey results, most teachers preferred to engage in existing CS projects (77%), rather than to create their own CS projects. A list with the projects that teachers reported to have engaged with can be found in Supplementary File D. Most teachers aligned the CS activities to the curriculum (59%) and engaged in projects that contained online elements (91%). Many ran the activities during school hours (54%) and preferred to engage students in groups (54%). The selected CS activities mostly combined indoor and outdoor activities (41%); 38% were outdoor-only activities, and 21% indoor-only activities. Two-thirds of the teachers reported that they did not request or require school or parental permission for their activities. Teachers neither received any funding or support (84%) nor did they collaborate with universities or other STEM centres (75%). Those who reported having some form of collaboration mentioned engaging in projects mainly initiated and designed by scientists, with only one teacher explaining how they reached out to a research centre to receive support on their own-designed project. Scientist-initiated collaborations included ready-made material given to teachers supplemented by a few progress meetings.

Regarding the science inquiry phases covered as part of the CS activities (Fig. 3, left), teachers engaged students mainly in data collection/analysis, such as identification (80%) and observation (75%). Other phases included data comparison (59%), extracting/synthesising data (45%), and summarising (50%), reflecting on (64%),

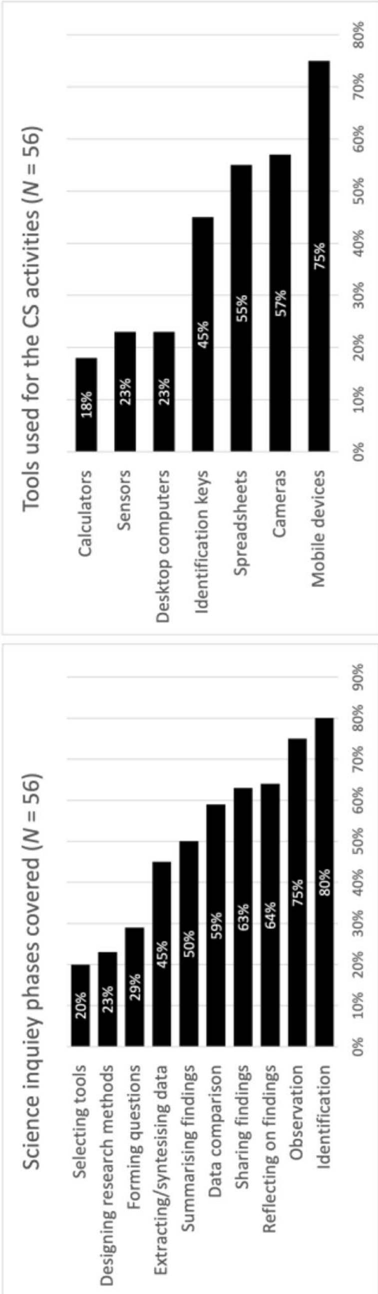

Fig. 3 Science inquiry phases covered in the CS classroom activities (left) and tools used (right)

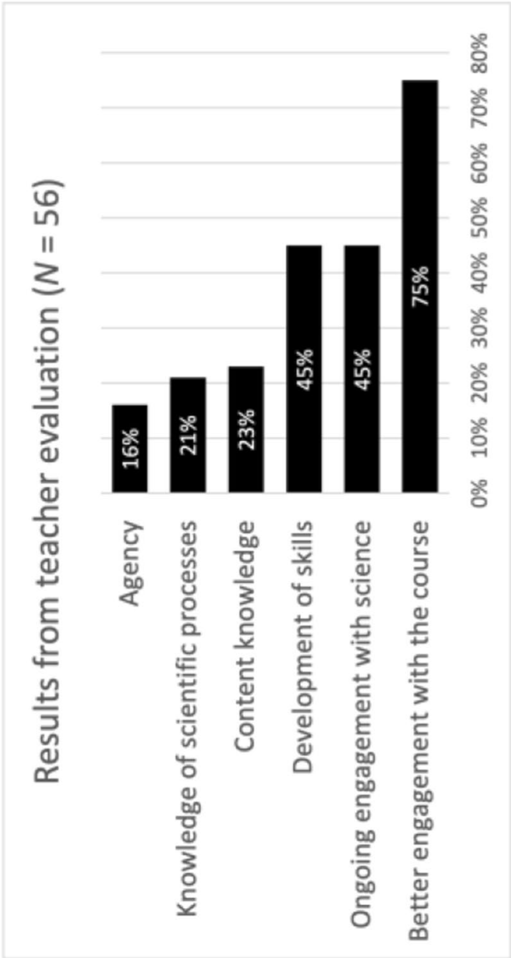

Fig. 4 Results from teacher evaluation of the CS activity

and sharing (63%) their findings. Less common phases were encouraging students to form their own questions (29%), designing research methods (23%), and selecting tools (20%). The most frequently used tools (Fig. 3, right) were mobile devices (75%), followed by cameras (57%), spreadsheets (55%), and identification keys (45%). The least common options were desktop computers (23%), sensors (23%), and calculators (18%).

Most teachers had completed their CS activities (64%) at the time they responded to the survey. Two-thirds of the participants (66%) reported that they informally evaluated the impact of the activity on their students. Results from teacher evaluation or reflection (Fig. 4) included better engagement with the course (75%), ongoing engagement with science (45%), development of skills (45%), content knowledge (23%), knowledge of scientific processes (21%), and agency (16%). Almost two-thirds (64%) mentioned that they had presented their CS activity findings at a student event/conference.

Interview Results

The interview data showed that the activities were conducted in different settings (online, blended, field-based, or a combination of these), on different CS platforms (e.g. iSpot, Zooniverse, and iNaturalist).

Teachers combined CS activities with *additional activities* that focused on improving student understanding of the nature of science, and scientific processes, and they even touched on socio-scientific issues:

"Students have very rich discussions about where the data, where the light pollution was concentrated, but also trying to get the kids to look very critically at data and thinking, 'Well, why is the majority of the data concentrated in Europe, with some spread throughout other English-speaking countries? Why is there no data in China?'" (Activities, additional activities, T20, 35–44, female, primary school teacher).

Overall Interpretation

In this theme, teachers describe how they executed the CS activities with their students. Overall, they explained the type and settings of the CS activities that they used, added that they employed some additional activities to better support learning within CS, and informed about external collaborations they may have had during the execution of the activity. Interestingly, teachers emphasised the use of existing projects with online elements (and especially mobile devices), the lack of funding and collaboration with scientists, the limited involvement of students in all aspects of research, and the positive effect of the CS activities on students' engagement with the course.

Challenges

Survey Results

The survey responses exposed some of the challenges that teachers faced when engaging in CS activities with their students. Slightly over half of the survey

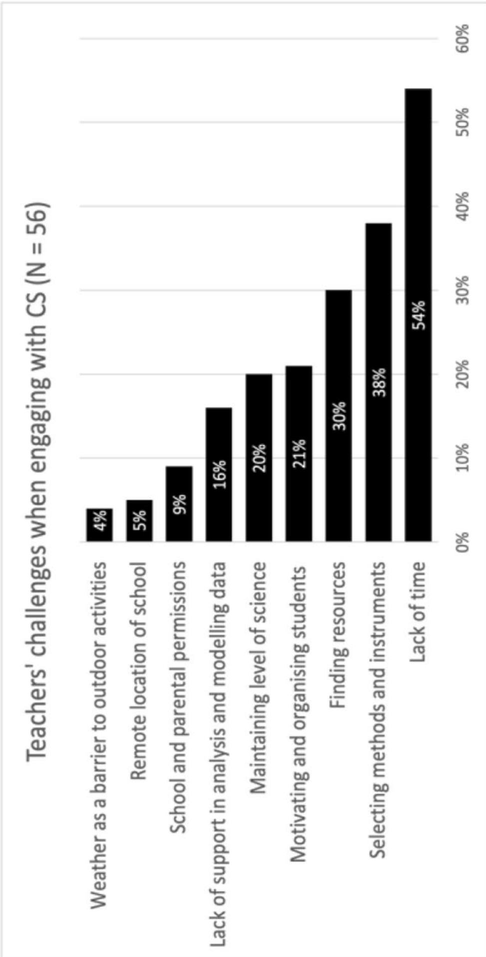

Fig. 5 Teacher's challenges when engaging with CS activities with their students

respondents (54%) mentioned finding time to organise and run the activity as their biggest challenge (Fig. 5). Other challenges related to the design of the activity to ensure learning is involved, selecting the right methods and instruments (38%), and finding *resources* to support learning around the CS activities (30%). Other challenges involved motivating and organising students (21%), maintaining the level of science involved in the activity (20%), and receiving support in analysing and modelling the collected data (16%). Gaining school and parental permission (9%) and dealing with external factors, such as the remote location of their schools (5%) and weather that does not allow outdoor activities (4%), were only challenging for very few teachers. However, nearly all of the participants (89%) reported that they were already planning to further engage their students in CS.

Interview Results

The interview data, as opposed to the survey data, underlined the importance of maintaining both student and teacher motivation, the lack of resources, and the difficulties in securing permission for the activities. Some of the further issues that were identified were dealing with students' negative attitudes towards science, preparing students to understand that they are contributing to real science, and considering students' other priorities, such as exams:

"The problem is that they think it is something to have fun, they don't think it is serious work! So, in the beginning, it is quite complicated because they say okay, we go into the laboratory with a computer or other things to make science, and they say it like a joke, but it is hard work." (Challenges, student motivation, T22, 35–44, female, secondary science teacher).

The interviews also revealed challenges associated with initiating and sustaining *teacher motivation*. Teachers who had already engaged in CS activities mentioned having intrinsic motives (for example, being part of research initiatives). They, however, recognised that they sometimes found it difficult to maintain their own motivation and they failed to recruit other teachers for the activities. The main reasons for the lack of motivation that the teachers mentioned were the absence of benefits, such as the lack of support in activity design, funding, and collaborations:

"There was no financial incentive, or any incentive or benefits for the students or the school or myself, other than just being part of the research." (Challenges, teacher motivation, T20, 35–44, female, primary school teacher).

Another challenge mentioned was bureaucratic procedures, such as parental permission, school permission, and related paperwork, which required even more of the teacher's time and interfered with the teacher's motivation and the timeline of the CS activities:

"The school had to sign permission. We had the students, they also had to give permission to be part of the research. So, the researchers came in and observed the classroom in action, they talked to some of the students who'd returned permission slips from their parents saying they could do that." (Challenges, permissions, T20, 35–44, female, primary school teacher).

Overall Interpretation

Difficulties in organising the CS activity and motivating students to participate were revealed as some of the major challenges. In particular, teachers reported a lack of time and support, and difficulties in designing and evaluating activities of scientific value. Another important challenge, raised by those who had to gain school or parental permission, was the bureaucracy they face, which is even heavier if the CS activity is accompanied by an evaluation or a study investigating, for example, individual outcomes. These challenges were summarised in an overarching topic as aspects that work against the teachers' motivation to engage in CS activities.

Recommendations

Survey Results

Motivating students was selected as the top recommendation (64%) for other teachers who want to engage in CS activities. As explained earlier in the "Survey Results" section, teachers used a range of incentives to motivate their students to take part, such as choosing topics that students are interested in, using more collaborative teaching approaches, and organising collaboration and events. Motivating students was followed by using technology (46%), integrating role-playing activities (29%), seeking support via professional development opportunities (11%) and other colleagues (7%), and using board notes and mapping tools (5%).

Interview Results

Teachers' recommendations for their colleagues, as identified in the interviews, were related to developing collaboration and supporting networks, balancing learning value and fun in science, and disseminating the activity outcomes.

In interviews, teachers also suggested that funds should be increased to cover their professional development, so that they can refine their engagement techniques and their knowledge of designing and evaluating CS activities. Collaboration among teachers, with other schools, universities and STEM centres, or via teacher networks (e.g. GLOBE) was also recommended as a way of receiving more support in implementing CS activities:

"Every country has a GLOBE coordinator; you have to find the contact. Usually, every country has a local webpage or even this international webpage has the country coordinator's contacts, […] this person will help with everything this teacher needs for starting." (Recommendations, collaboration and support, T21, 45–54, female, secondary science teacher).

Planning to overcome students' negative attitudes towards science was suggested by interviewees as one of the first steps in the activity design and implementation. Teachers recommended conveying to students how much fun science can be but without losing the balance between learning gains and fun activities:

“I would focus more on how science works. So, they understand that it is not just something to go into the laboratory that is fun only, it is really hard work. But at the same time, I would try and unpick what is actually interesting and fun in this topic overall” (Recommendations, value and enjoyment of science, T2, 35–44, male, secondary school biology teacher).

Finally, teachers recommended that the outcomes of the CS activities should be disseminated. Disseminating findings can involve presenting posters at student and teacher conferences, but also publishing scientific articles in academic journals and presenting at scientific conferences, in collaboration with scientists:

“It would be nice to try and get it published within the scientific community, rather than just keeping it at school level, but that’s the long-term dream. I’m much more likely to contribute towards something that’s at student level, either through a student conference or maybe a poster competition.” (Recommendations, Dissemination of findings, T18, 35–44, male, secondary science teacher).

Overall Interpretation

Teachers’ main recommendations for colleagues who would like to engage in CS activities involved developing collaborations with supporting networks and motivating students to participate. For greater activity support and success, they suggested using technology, role-playing, and board notes, but also an emphasis on the value and fun in CS. Furthermore, the dissemination of activities was suggested to motivate students and teachers and contribute to the scientific community. Recommendations at a policy-level focused on receiving funding towards their professional development for the use of CS in the classroom.

Discussion

Information about teachers’ experiences with CS can improve the understanding of how they act as intermediaries between CS and education and provide valuable insights into how they can be further supported in bringing authentic science into the classroom. The integration of survey and interview findings contributed to making sense of the whole feedback and developing an overall interpretation of each topic, although there were some minor differences between the results from the two methods.

Summary and Reflections

Teachers stated that the main motivation to participate was interest in the topic (e.g. Rotman et al., 2014) and learning (e.g. Raddick et al., 2013), similar to the motivation of other volunteers in CS projects. However, our study also revealed other distinctive types of motivation, such as using CS to bring novelty to teaching, for professional development, and to use mobiles and other technology with their students. Our findings thus confirm previous research on teachers’ motivation for engaging with CS, highlighting the importance of bringing novelty to their teaching practices, exploiting technology for student engagement (Aristeidou et al., 2021), and engaging in hands-on experience (Doyle et al., 2017). Previous findings also reported that research-active teachers have an increased sense of professional worth and self-belief (Rushton & Reiss, 2019). Our results, however, did not find altruistic motivation, such as a contribution to the community and science, to the same extent as other studies (e.g. Bracey, 2018).

Teachers motivated their students by promoting the students' interest in CS activities, using engaging teaching approaches and technology, and collaborating with other stakeholders, such as scientists, parents, and the school community. These findings reflect the enthusiasm of both teachers (Aristeidou et al., 2021) and students (Rushton & Reiss, 2019) to become involved in real-world tasks and challenges. It is interesting to note how external drivers were used as engagement methods, with teachers liaising with external actors and attending events, field trips, and outdoor activities while framing the activities for students as doing science that helps scientists. All these methods offered teachers a way to connect their lessons with real-world issues and students' everyday life experiences to achieve the intended participation and learning outcomes.

Teachers' activities during participation in CS projects may reflect their preferences, their capacity, and their connections. For example, nearly all of this study's teachers engaged in projects with online elements. As reported in previous research with teachers, this could be attributed to several factors. For instance, online projects are accessible to schools in different locations and to students of different ages (Aristeidou et al., 2021); a further factor could be that people generally participate where they can easily access such activities (Pocock et al., 2021) or it could be due to young people's preference for tools with displays when engaging with science (Cairns et al., 2021). The participation pattern described by teachers matches that of contributory CS project types, which are the most common types of CS projects, in which participants are generally only involved in data collection (Smith et al., 2017). Teachers involved students mainly in such data-collection activities, such as making observations, instead of engaging them in activities of higher inquiry levels (such as forming their own questions or designing their own methods). An explanation for this might be the limited number of CS projects that allow, but also support, opportunities for co-creation and collaboration in most or all aspects of the research. This lack of support may be more acute when teachers coordinate the CS project without any external help from scientists and researchers. In response to this lack of bottom-up support, several platforms are currently being developed with the aim of supporting citizen-led research; an example is the nQuire platform (https://nquire.org.uk/).

According to teachers' reports, the primary outcomes of this contributory participation involved better engagement in the classroom, followed by increased engagement with science and science skills development. Other learning-related outcomes, such as content knowledge, scientific processes, and agency, were also reported, but to a smaller extent. Overall, this finding substantiates findings from classroom-based CS research studies on students' learning (e.g. Castagneyrol et al., 2020; Kelemen-Finan et al., 2018). It, however, also reflects what outcomes teachers were most interested in achieving (as opposed to researchers), such as engagement in the classroom. Further, it is essential to note that most of the teachers selected CS activities aligned to the curriculum and developed additional activities to support students' learning and understanding of the scientific topics.

The teachers' efforts as intermediaries between CS and formal education were mostly not accompanied by external funding, support, or collaboration with scientists/researchers. This lack of support was evident in their self-reports and may have implications for students' self-trust in collecting reliable data (UC Davis Centre for Community and Citizen Science, 2018), as there is an observed positive association between sustained engagement with project scientists and students' continuous interest and participation in the project. The most significant challenges they reported were finding the time to organise the activity, developing the right methods and instruments, and finding resources. Concurrently, teachers occasionally struggled to maintain students' and their own motivation to participate in CS. To address the lack of students' motivation, teachers' recommendations highlight the importance of technology and teaching approaches. Concerning teachers' motivation, their advice to other teachers was to look for professional development opportunities and to engage in collaborations with other teachers and scientists. Despite the challenges they faced, most survey respondents reported that they already had plans to further engage their students in CS soon.

Implications for Teachers and Citizen Science Researchers

This understanding of the motivation and experiences of teachers who act as intermediaries between CS and formal education has important implications for professional development designers, CS education researchers and designers, and teachers who are interested in engaging students in CS. First, teachers recommend professional development in formal education to support their CS teaching practice. These initiatives should provide teachers with (a) an understanding of CS as a concept, (b) guidelines and support on how to implement CS activities in their classroom (Lorke et al., 2019), and (c) a sense of collegiality and an experience with an active professional community of practice (Pop et al., 2010). Such capacity building could form the first step towards implementing CS effectively in classrooms. It could address many challenges the teachers reported in our study, such as how to align the activity to the curriculum or how to design methods and instruments. Another means of support could be the development of a mentoring model among teachers in CS to address practical difficulties that arise during the implementation of such innovative classroom practices (see Mandrikas et al., 2021). Second, CS educational researchers could support teachers' efforts by developing repositories that catalogue CS projects, activities, and instruments and other resources that can be searched based on the curriculum aim that each one may serve. In this way, teachers' additional effort would be acknowledged and reduced as much as possible. Third, CS designers could support teachers' efforts by recognising their motivation to bring novelty into their teaching and to develop professionally and, thus, by formulating relevant retention and recruitment strategies. For example, CS designers could include descriptions of their project activities in the abovementioned repositories, in which they inform teachers about how to engage and share resources with them in the project. Finally, teachers who want to conduct CS activities with their students might benefit from their colleagues' recommendations in this study, such as the recommendations about ways to motivate their students and support themselves. The recommended actions could eventually equip teachers with the necessary motivation, confidence, knowledge, and resources and, thereby, contribute to the successful integration of CS into school classrooms.

Limitations

The present exploratory study has shed light on teachers' experience in classroom-based CS of which we currently have limited knowledge, although CS has been increasingly used in school classrooms. The limited number of teachers who have already experienced CS, in combination with their limited available time, allowed a rather small number of participants. Teachers' insights facilitated our understanding of how to engage and better support them in classroom-based CS activities. However, given the convenience sampling method used in this study, the results should be interpreted with caution, as they are not location-based or focused on a particular schooling context. Future large-scale studies could validate this study's findings and allow comparisons of different school types and schooling context to propose more location and context-specific recommendations. For example, to explore teachers' professional motivation with respect to their local curriculum context and demands.

Conclusions

This study explored the motivation and experiences of teachers who involved their students in CS activities. The findings of this study indicate that teachers experienced the benefits that CS can bring to their teaching practices and students' learning at first hand. However, they did not feel supported adapting the activity for classroom learning purposes. We are confident that our research will serve as a base for further research on how to embed CS in the classroom and create professional development initiatives and supporting networks for teachers who want to engage in CS activities. We also hope other teachers will be inspired to consider implementing CS in their classrooms based on their colleagues' experiences as detailed in this study.

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Data Availability Not applicable.

Code Availability Not applicable.

Declarations

Ethics Approval The current study has been reviewed by, and received a favourable opinion, from The Open University Human Research Ethics Committee (reference number: HREC/3378/Aristeidou), http://www.open.ac.uk/research/ethics/.

Consent to Participate Informed consent to participate in the study was obtained from participants.

Consent for Publication Informed consent from individuals to publish their data was obtained.

Conflict of Interest The authors declare no competing interests.

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