ORIGINAL RESEARCH

In pursuit of mutual benefits in school-based citizen science: who wins what in a win-win situation?

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Abstract

In a typical citizen science scenario different groups of people take on various roles in a research process that is often coupled with educational, social or personal objectives. A widely accepted viewpoint asserts that such an endeavor should bring benefits to all involved parties and that no participating individuals should act *in service* of others or of the end goal. However, the large variety of implementation models, of participating individuals, and of desired impacts, leaves room for inconsistencies regarding what outcomes count towards mutual benefits. In this article we examine the ambiguity embedded in the definition of mutual benefits in citizen science and take a stand towards its resolution. We use school-based citizen science as a model for a multi-stakeholder, multi-objective citizen science. Focusing on teachers and scientists that work together to facilitate student participation in citizen science, nine teacher-scientist pairs that collaborated on nine different school-based projects were included as study participants. We examined participants' motivations for school-based citizen science and perceived costs and benefits using a questionnaire that they filled while verbally explaining their answers. Our findings reveal multiple ways in which teachers and scientists tapped into their professional, social and personal identities to create multilayered sets of motivations and perceptions of benefits. Thus, we argue that a mutualistic perspective of citizen science should take this complexity into account and be prepared to answer multi-faceted expectations, which may reside not just among but also within participating individuals.

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Research rationale

The challenge of mutual benefits

In the last decade the practice and research of citizen science has grown prolifically, spurring the development of diverse models for doing and thinking about citizen science (Haklay et al., 2021), and advancing the state-of-the-art appreciation of its impact and significance for science, citizens, and society (Vohland et al., 2021). One of the cornerstone values of the field is the view of citizen science as a mutualistic endeavor that brings benefits to all involved parties. This is manifested in various collectively authored position papers, for instance, in principle #3 of the ten European Citizen Science Association (ECSA) principles of citizen science (Robinson et al., 2018):

> Both the professional scientists and the citizen scientists benefit from taking part. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence e.g. to address local, national and international issues, and through that, the potential to influence policy.

These words convey a wide perception of benefits relevant for participating individuals, including short and long-term benefits, tangible outputs, emotional effects and more. However, the notion of mutualism has a much longer history than that developed in citizen science research, with roots stemming from the initial adoption of biological theories for explaining social behavior (Hamilton, 1964). Thus, a large and well-established literature that studies social interactions maintains that mutualistic partnerships are defined by directly utilizable benefits for all involved parties (Birch, 2017). In the case of citizen science, such benefits may include research publications for professional scientists, or learning of a useful skill for participating citizens. When it comes to benefits that are less tangible or do not carry concrete consequences that improve an individual's practical state, such as feelings of satisfaction from one's contribution or potential for wider (e.g., policy) changes, the socio-evolutionary perspective would not tally those towards mutual benefits (Birch, 2017, p. 35). This point of view contrasts an inclusive definition of benefits, such as the one perceived by the citizen science community (e.g., the ECSA principles), that generally considers these types of benefits as valuable and applicable in mutualistic collaborations.

The apparent contradiction between the two perspectives exists not only on a theoretical level but also in practice. Much progress has already been made towards achieving mutual benefits in citizen science partnerships, ensuring its value towards both scientists and citizens. For scientists, development of appropriate methodology and implementation of protocols can lead to rigorous research (Balázs et al., 2021; Kosmala et al., 2016; McKinley et al., 2017; Shirk & Bonney, 2018). Such practices may negate suspicions among the scientific community regarding the validity and applicability of citizen science methods (Burgess et al., 2016; Riesch & Potter, 2014; Riesch et al., 2013). For citizens, norms such as the ECSA principles or Responsible Research and Innovation (RRI) guidelines (Eleta et al., 2019; Senabre Hidalgo et al., 2021; Smallman, 2018) secure the attention to citizens' needs and aspirations within partnerships. Still, citizen science projects of different kinds recurringly encounter difficulties around additional challenges, such as establishing open and trustful communication among partners, resolving questions of ownership and division of responsibilities, bridging knowledge and cultural gaps, and ensuring that individual goals are not dominated by collective ones (Hoover, 2016; Land-Zandstra et al., 2016; Martin,

2017; Riesch et al., 2013). Thus, while the inclusive perspective of mutualism in citizen science reflects the broad range of possible impacts, there are cases where it seems to cast a shadow over legitimately narrower motivations and expectations. Considering this, the rationale of this study stems from both theoretical and practical obstacles for achieving mutual benefits in citizen science. The former revolves around the ambiguity embedded in the definition of mutualism, and the latter around the complexity brought forward by science-society interactions. In this article, we provoke an empirically based discussion of these challenges, focusing on the arena of school-based citizen science.

Why schools?

The question of available impacts and benefits gains new nuances in school-based citizen science, in which students take part in citizen science activities as part of their classes. Such projects intersect two institutions that have well-established epistemological and procedural traditions, in an attempt to reach both scientific and educational results. This "double-headed" objective often raises difficulties in balancing between scientific and educational goals, scientists' and schools' visions for the project, and differing practices and routines (Gray et al., 2012; Penuel et al., 2006; Radinsky et al., 2001; Roche et al., 2020; Zoellick et al., 2012). Cases of citizen science in formal education contexts are less studied than other forms of citizen science, leading to a lack in specialized knowledge and design guidelines. Thus, in school-based citizen science the concern of mutual benefits is tinted by somewhat heightened tones, making it a good model, in our opinion, for examining the notion of mutualism in citizen science.

One characteristic of school-based citizen science is the involvement of multiple stakeholders that orchestrate students' participation. In many cases, the joint leadership of teachers, scientists and educational specialists determines the nature of students' engagement. The Taking Citizen Science to School (TCSS) initiative, which served as the context for this research, fosters a network of such research-practice partnerships in which educational researchers work together with schools and research teams on designing and implementing citizen science projects with the participation of students (Hod et al., 2018). The complex array of interactions between this diverse set of partners, and its impact on the partnerships' affordances, are yet to be fully studied. Of special interest is the interaction between teachers and scientists, both having crucial roles in these partnerships that are often off the beaten path of their usual professional occupations.

Research goals and questions

The goal of this study is to examine the spectrum of benefits and the challenge of mutual benefits in teacher-scientist partnerships built around school-based citizen science projects. Focusing on the perspectives of teachers and scientists, special consideration is given to elements that uphold the sustainability of such partnerships. We ask two research questions:

RQ1: What motivates teachers and scientists to participate in school-based citizen science projects?
RQ2: What benefits and costs are perceived by teachers and scientists participating in school-based citizen science projects?

Through these questions we expect to gain an understanding of why and to what ends teachers and scientists take part in school-based citizen science. Using a methodological setup that juxtaposes teachers and scientists that collaborated on joint projects, we investigate differences and similarities between these two groups and within each group. These insights are instrumental in evaluating benefits and mutualism in the partnerships.

Theoretical background

Benefits of school-based citizen science

In citizen science, individuals that are not professional scientists, often referred to as citizen scientists, participate in performing scientific research with varying levels of engagement (Bonney et al., 2009). In projects categorized as contributory or collaborative, citizens primarily contribute data or take part in either research design or data analysis of a scientists-led research (Shirk et al., 2012). In projects categorized as co-created (Shirk et al., 2012) or extreme citizen science (Haklay, 2013), citizens assume high or complete responsibility for managing and conducting the research.

The research and practice of citizen science has accelerated in recent years (Bautista-Puig et al., 2019). In many projects, citizens' participation boosts data collection or processing, and may provide data not readily available otherwise (Fritz et al., 2019; Mckinley et al., 2017; Robinson et al., 2020). Co-created and community-based projects often address issues of high public relevance, with a potentially increased impact due to high levels of citizen engagement (Ballard et al., 2018; McKinley et al., 2017). Recent research shows that achievement of scientific results is dependent not just on rigorous scientific methods, but also on effective engagement of citizen scientists (Golumbic et al., 2020).

For citizens, participation in citizen science can have affective, cognitive, social and behavioral impacts (Phillips et al., 2019), which may ensue even in projects with low engagement profiles (Kloetzer et al., 2016; Phillips et al., 2019). Possible impacts include increased interest, motivation and self-efficacy for science, improved scientific knowledge, and active stewardship (Phillips et al., 2018). Engagement with citizen science can be a transformative process, both for citizen scientists as well as participating scientists, and may be accompanied by participants' creative contributions (Jennett et al., 2016).

School-based citizen science offers unique challenges to mutual benefits

Youth engage with citizen science in both school-based and out-of-school environments, together with their families or with the guidance of instructors, teachers and others (Kloetzer et al., 2021). When youth participation occurs within an educational context, an added educational value is expected or required. Indeed, many youth-focused studies have demonstrated various unique learning outcomes (Ballard et al., 2017; Bonney et al., 2015; Calabrese Barton & Tan, 2010; Harris et al., 2020; Kelemen-Finan et al., 2018; Silva et al., 2016).

School-based citizen science, in which students participate in citizen science as part of their school activities, brings forward several unique challenges for achieving mutual benefits (Kloetzer et al., 2021; Roche et al., 2020). First, unlike other citizen scientists, student participation may not be a free-choice activity and that may affect students' motivations to participate. Second, student participation is typically mediated by teachers. Thus,

a school-based implementation is dependent on teachers' actions and reactions to internal and external factors (Kali et al., 2019). These, in turn, are affected by teachers' capacities, attitudes, motivations, and expectations. Third, both schools and citizen science projects have many constraints and administration requirements, making the logistics of enacting citizen science activities within schools challenging. Lastly, and possibly most critically, it can be difficult to ensure scientific results that adhere to scientific standards as well as learning outcomes that adhere to the school's educational agenda or the state/national curriculum. Questions such as the scope of students' roles and responsibilities, what activities do the students commit to, and what are the expected project outcomes, are not easily resolved (Gray et al., 2012; Zoellick et al., 2012).

Existing research already offers important guidelines for overcoming the difficulties described above. We here delineate some that seem particularly promising, dividing them into several dimensions of what should become a holistic solution:

- **Brokering between partners:**
  Since collaborating parties (schools, scientists) come from different professional and institutional backgrounds, it is highly instrumental to have a third party that understands the needs of both sides and can intermediate negotiation of partnership processes (Penuel et al., 2006; Zoellick et al., 2012). Educational researchers, for example, are highly suited for this role (Benichou et al., 2022).
- **Facilitating the development of a shared mindset:**
  To form a solid conception of how the partnership should work, partners (scientists, teachers, and students) should get familiarized with definitions and examples of citizen science, as well as the underlying philosophy of the field (Lorke et al., 2019). To bridge over differing epistemologies and procedures, it may be useful to center learning activities around themes of Nature of Science, introducing teachers and students to the values and norms of real-world science (Gray et al., 2012). Similarly, scientists may be acquainted with the nature of schooling and school practices and learn to adapt to them (Benichou et al., 2022).
- **Skill-building and growth opportunities for teachers and scientists:**
  Various strategies, such as professional development activities or other types of supports, can be used to foster the development of relevant knowledge, communication skills, and feelings of ownership and meaningfulness towards the citizen science partnership, among both teachers and scientists (Benichou et al., 2022; Kali et al., 2019; Penuel et al., 2006; Roche et al., 2020; Zoellick et al., 2012).
- **Designing learning environments to support mutual benefits:**
  Existing suggestions for appropriate designs of student activities in citizen science partnerships are diverse and sometimes even contradictive. Co-created projects, where students are highly involved in research design, can lead to high student engagement and produce valuable research alongside significant learning outcomes (Gray et al., 2012; Roche et al., 2020). A different approach is to separate students' research questions from those of the scientists, even as they both use the same collected data. This design sidesteps knowledge and expertise gaps while ensuring that the research stays relevant and interesting to both students and scientists (Zoellick et al., 2012).

As supportive as these and other guidelines are, their application is far from trivial and the challenge of mutual benefits in school-based citizen science persists. Implementing citizen science in schools is a disruptive process in traditional schooling (Kali et al., 2019; Mueller et al., 2012; Weinstein, 2012), not unlike the disruptive nature of citizen science

itself as a research method that challenges traditional scientific norms and protocols (Shirk & Bonney, 2018). School-based citizen science links these two "disrupted" institutions, making mutual benefits a difficult goal to achieve.

Motivations and expectations in school-based citizen science

Teachers have both cognitive and affective goals for their students

The benefits people find in citizen science are closely related to the incentives that lead them to initiate and sustain engagement. Current research on motivations in citizen science mostly focuses on citizen participants who are adult volunteers, limiting its relevance to motivations in school-based citizen science. Shortly summarized, such studies show that citizen scientists are often motivated by personal interest, enjoyment, social interaction and a sense of contribution—to science, to the environment or to other people (Land-Zandstra et al., 2016, 2021; Levontin et al., 2018; Nov et al., 2011, 2014; Raddick et al., 2013). A study of online citizen science found that such motivational factors characteristically reinforce the first stages of engagement, whereas sustained participation is driven by continued interest and by the capacity for on-going involvement (Jennett et al., 2016).

There are a few studies that examine teachers' motivations in school-based citizen science. These show that teachers are concerned with both cognitive and affective benefits for their students. Expected cognitive outcomes primarily include advancing students' scientific knowledge and skills (Lipshitz et al., 2021; Scheuch et al., 2018). Affective benefits include enticing curiosity, interest and enjoyment, engaging children with science in inspiring ways, and inducing feelings of value and empowerment (Kaplan Mintz et al., 2021; Kountoupes & Oberhauser, 2008; Lipshitz et al., 2021). School-based citizen science projects in the discipline of ecology often aim to impact students' attitudes towards the environment and entice feelings of connectedness to nature (Lipshitz et al., 2021; Scheuch et al., 2018). Teachers often perceive citizen science as a pedagogical tool that can enhance their teaching, offering new pedagogical practices and a hands-on, active and authentic way for learning (Kaplan Mintz et al., 2021; Lipshitz et al., 2021). Furthermore, teachers' own professional identity may be expanded as they come to see themselves as agents of pedagogical change and innovation (Kali et al., 2019) as well as partners with an important expertise for enhancing science within research-practice partnerships in school-based citizen science (Benichou et al., 2022).

Scientists "walk a difficult line" in their expectations for citizen science

Scientists' motivation to participate in school-based citizen science is an under-studied topic, yet much can be learned from studies of scientists' attitudes towards public engagement and other forms of citizen science. Scientists' perceptions of the public and of public engagement follows, to a great degree, the deficit model of science communication (Trench, 2008). Scientists often believe there is a lack in scientific literacy among the public, and their public engagement efforts are often directed at remedying this issue (Besley & Nisbet, 2013; Rose et al., 2020). Nevertheless, these stances are accompanied by a growing support, especially among younger scientists, in dialogic forms of public engagement and in public participation in scientific research (Besley et al., 2018; Rose et al., 2020). As put by Besley and Nisbet (2013), "scientists seem to walk a difficult line both in recognizing
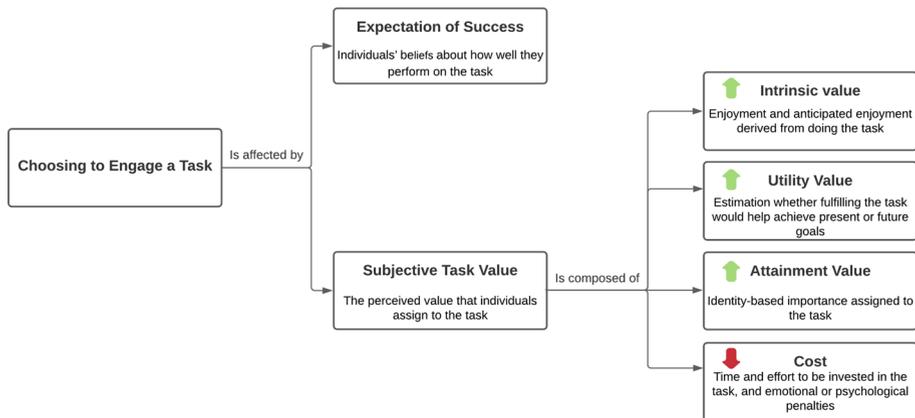
Fig. 1 The expectancy-value theory of motivation (simplified model based on Eccles & Wigfield, 2020)

the right of citizens to play a role in decision-making while having reservations about the public's capacity to do so" (p. 651).

This observation is reflected in studies of scientists' attitudes towards citizen science. Golumbic et al. (2016) interviewed 10 scientists that were involved in a single citizen science project, concluding that they had difficulty with the idea that the public can perform scientific practices and make an actual contribution to science. Burgess et al. (2016) found that biodiversity scientists and citizen science project managers strongly preferred the involvement of college students and graduates in citizen science, over that of other citizens. In this study, over half of the scientists believed citizen science data suffers from quality assurance issues, and more than a quarter did not think that amateurs are able to collect data for their research. Data quality was also a major concern for scientists working with OPAL citizen science projects (Riesch & Potter, 2014). In all three studies, scientists posed educational and public awareness outcomes as major incentives for citizen science. Yet, the OPAL scientists also acknowledged that participation should produce personally relevant benefits for citizens. Junior scientists in the study by Golumbic et al. (2016), as opposed to senior ones, viewed public engagement as part of their role as scientists and supported the notion that public engagement can benefit both the public and themselves.

The expectancy-value theory of motivation

School-based citizen science can be framed as a partnership in which each side invests time and resources while expecting certain outcomes. Therefore, we find the Expectancy-Value Theory of motivation (Eccles & Wigfield, 2002) a powerful analytical framework to study such partnerships. This theory was conceptualized with the primary intention of explaining students' academic performance and has since been developed and implemented in other contexts as well (e.g., Green, 2002; Lynd-Stevenson, 1999; Savolainen, 2012). It is based on the model illustrated in Fig. 1.

The current study focuses on the Subjective Task Value of the expectancy-value theory (see Fig. 1) and the perception of benefits and costs by scientists and teachers. As depicted in the model, the subjective task value is seen as a net value derived from the costs and the benefits of the task. Of the three value types, attainment value is closely connected to an

individual's sense of identity and to "the extent to which tasks do or not allow persons to manifest those behaviors that they view as central to their own core sense of themselves or allow them to express or confirm important aspects of their central selves" (Eccles & Wigfield, 2020, p. 5).

A questionnaire for identifying expectancies and subjective task values was originally developed for studying motivations for learning in elementary school students (Eccles & Wigfield, 1995). It was based on self-reported information using Likert-type questions. Later studies implemented modifications on this scale, tailored to specific research contexts. One of the most validated among the modified scales was created for research on motivations in physical education (Xiang et al., 2013).

To summarize the theoretical background for this research, school-based citizen science holds promise for instilling the kinds of benefits seen in general citizen science projects, yet a successful implementation requires careful consideration. The continuing practice of school-based citizen science is foremostly dependent on the good will and agency of stakeholders such as teachers and scientists. Therefore, in this study we wish to uncover what outcomes sustain the engagement of these individuals in school-based citizen science partnerships. Through this examination, we aim to shed light on the concept of mutual benefits in citizen science and to advance capacities for materializing this objective in citizen science projects.

Methodology

Cases and participants

The study includes nine cases of teacher-scientist partnerships that developed around nine citizen science projects, of which eight are a part of the TCSS network. The projects were each led by different teacher-scientist teams (often including several individuals of each party). Additionally, seven cases also included the involvement of educational researchers. In each case, two leading figures in the partnership, one teacher and one scientist, were included as study participants. More details about the cases and the participants are presented in Table 1.

The partnerships facilitated the participation of students in citizen science projects which were mostly contributory (i.e., students' main contribution was the collection or processing of data). In all cases, students' participation was accompanied by a series of learning activities that were designed at the partnership level and lasted several weeks with 10–30 teaching hours, mostly around 20 hours. The activities typically included learning of background material, hypothesizing and asking questions, collecting data outdoors, performing data analysis, and drawing conclusions. Collected or processed data was typically part of a larger citizen science compendium built from the contributions of multiple schools or communities. Students were aware of scientists' research goals and in seven cases had direct contact with at least one scientist. Students' own data analysis was typically independent of the scientists' research.

Data collection strategy

A questionnaire was developed consisting of two parts, each corresponding to the study's research questions (see Online Resource 1). The first author of this article met with each

Table 1 Partnerships and participants included in the study

Partnerships					Study participants	
Object of research	Scientists' research interest	Students' main contribution to the research	Students' grade level	Duration (in school years)[a,b]	Teacher	Scientist
Air quality	Testing operability and applicability of personal air quality detection units	Collecting air quality data using personal detectors	10th	1	Science teacher and a geo-chemistry graduate student	University faculty, industrial engineering specialist, head of research in the project
Bees	Detecting and classifying species of wild bees	Observing and recording the presence of wild bees	6th	1	Science and special-ed teacher	Master's degree in science education and self-educated scientist, head of several researches in an ecological research center
Butterflies	Monitoring butterfly populations in a post-fire recovery area	Observing and recording the presence of butterflies	6th	1	Science teacher and teacher team leader	Full-time researcher in a research institution, head of research in the project
Dolphins	AI pattern recognition in dolphins' voice spectrograms	Manual tagging of dolphins' voice spectrograms, for AI training	8–9th	2	Science teacher and teacher instructor, PhD in Education	University faculty, electrical engineering specialist, head of research in the project
Jellyfish	Characterizing and predicting jellyfish distribution patterns	Observing and recording the presence of jellyfish along coastlines	4–6th	2	Science teacher and teacher instructor	Post-doctorate, marine ecology specialist, one of the founders and scientific manager of the project
Mammals	Understanding the effect of different land uses on the distribution of small mammals	Collecting footprint data as indication for mammalian occupancy of territories	4th, 6th	2	Math teacher, school vice-principal, interested in environmental education	Doctoral student in Ecology, founder and manager of the project
Mapping	Algorithmic calculation of optimal walking paths for the visually impaired	Mapping urban pathways in an open-source mapping platform	10th	1	Geography teacher	University faculty, geoinformation specialist, head of research in the project

Table 1 (continued)

Partnerships

Object of research	Scientists' research interest	Students' main contribution to the research	Students' grade level	Duration (in school years)[a,b]	Study participants	
					Teacher	Scientist
Radon	Assessing risk of population exposure to Radon levels within buildings	Measuring levels of the Radon gas at homes using personal kits	9th	2	Science teacher and teacher team leader, leader of teacher communities of practice	Graduate student in civil engineering, part of the research team leading the project yet not in a research role
Sleep	Characterizing sleep patterns of youth	Recording personal sleep logs	10th	1	Science teacher, teacher technological instructor	University faculty, medical sciences specialist, co-head of research in the project

[a] At the time of data collection for this study (some of the projects are ongoing)

[b] A 2-year duration indicates that the teacher-scientist partnership lasted for two years, directing two consecutive enactments of the project

participant individually in a recorded video call, in the time period of May–August 2020. Video sessions began with a short interview for collecting basic biographical data and a general description of the participant's involvement in the citizen science project. Then, an online version of the questionnaire was filled by the participants as they shared their screens with the interviewer. They were instructed to *think-aloud* (Charters, 2003) and voice their thoughts while working, explaining their answers and expressing any ideas and associations that came to mind. Having the questionnaire responses accompanied by think-aloud statements allowed us to corroborate the quantitative analysis, perform additional analysis that elaborates on the questionnaire data, and fine-tune our interpretation of the results. Efforts were made to minimize possible bias that this qualitative addition may have introduced. Specifically, the interviewer did not pose further questions as participants were going through the questionnaire, nor did she actively prompt for verbal statements. However, when verbal statements were initiated by participants, clarifications or details were asked for as seemed fit. Sessions typically lasted 40–60 min. Recorded sessions were later transcribed.

Data collection and analysis for RQ1

Questionnaire development

To understand what motivates teachers and scientists to participate in school-based citizen science, a list of known motivations for school-based citizen science was constructed based on a review of current literature. Five studies were selected to represent scientists' motivations, of these three were studies of scientists' views towards public engagement (Besley, 2015; Burchell et al., 2009; Davies, 2008) and two of scientists' views towards citizen science (Golumbic et al., 2016; Riesch & Potter, 2014). The studies were selected based either on comprehensiveness (large number of participants) or relevance (specific to citizen science). Two studies were selected to represent teachers' motivations (Kountoupes & Oberhauser, 2008; Scheuch et al., 2018). To complement data sources for teachers' motivations, three interviews with teachers experienced in school-based citizen science were conducted, asking about their own motivations for school-based citizen science. The interviews were performed with teachers who are not participants of this study.

To compile a comprehensive list of motivations for school-based citizen science, the data sources (seven studies and three interviews) were analyzed using an adapted thematic synthesis method for systematic reviews of qualitative research (Thomas & Harden, 2008). The texts of the "Results" chapters in the articles, and of the transcribed interviews, were free-coded line by line. One study (Besley, 2015) consisted of a survey and was not a qualitative study. Here, survey questions served as codes. All codes were organized into thematic categories, resulting in 101 statements that fell under the "motivations for public engagement/citizen science" category. These included both explicit statements of motivational drivers as well as expressions of favored outcomes. Motivational codes were organized into 32 descriptive themes and divided into four overarching analytic themes: scientific, educational, social and personal motivations. To allow motivations to be ranked by study participants, the list was further reduced to 15 items by continued synthesis within each analytical theme. In the final list, each theme consisted of 3–5 items, with two of the items ascribed to two different themes. The final list of 15 motivational items is presented in Table 4 (in the Results chapter), and in the questionnaire content outlined in Online Resource 1.

Participants were asked to rank motivational items according to how important they are to them. Since ranking, especially of a large number of items, is a task susceptible to bias (Ben-Akiva et al., 1992), the chore was divided into two stages, limiting the number of choices participants had to make at each step. First, participants were asked to divide items into three groups—most important, mediocrely important, and least important, under the restriction that each group must include exactly five items. Second, participants ordered the items within each group, from most to least important. This process concluded with a list of 15 motivational items ranked by importance (rank 1 to the most important item, up to rank 15 for the least important item).

Clustering of motivation rankings

To analyze similarities and differences of ranked lists, hierarchical clustering was administered on both rows (motivational items) and columns (participants) of the data matrix using an online statistics tool package (Wessa, 2017). Clustering was performed using Ward's minimum variance method (Contreras & Murtagh, 2015). Prior to clustering, dimensionality of the ranking data was further reduced by dividing ranked items within each list into five bins, such that the three most important items were assigned to bin #1, the next three to bin #2, etc. Thus, each list was reduced from 15 different ranks into five distinct ones (actual ranks assigned were 1, 3, 6, 9 and 12). Clustering results were visualized as a heatmap (see the Results chapter).

While acknowledging that statistical methods are available for clustering of ranked data and may produce more accurate results (e.g., Brentari et al., 2016; Jacques et al., 2014; Saito, 1980; Werry & Kaptein, 2016), the heuristics used in this study were chosen because of the relatively low number of participants and motivational items, and the lack of valid statistical assumptions regarding the data. While the chosen method may not ensure rigorous clusters, it immensely assists in detecting patterns within the data matrix.

Coding of motivation-related statements

To support findings from the clustering analysis, and to further identify motivations for school-based citizen science expressed by study participants, transcripts of the online sessions were analyzed, dividing statements into descriptive categories. 90 motivational statements verbally expressed by participants were identified and subjected to bottom-up thematic analysis (Boyatzis, 1998; Erlingsson & Brysiewicz, 2017). Each statement was condensed and coded, followed by a process of reduction by categorization. This process resulted with a hierarchical tree containing 19 motivational categories, of which the most prominent ones are presented in Fig. 3 (in the Results section). To verify coding reliability, a second coder independently assigned 30 of the 90 statements to the motivational categories, resulting in 87% overlap with the first coder (26 of 30 statements). In cases where multiple categories were assigned, of which at least half were matched yet there was no complete agreement between coders, only matched categories were taken into consideration.

Data collection and analysis for RQ2

Calculation of EVT-related indices

Analysis of teachers' and scientists' perceived costs and benefits was based on the Expectancy-Value Theory (EVT) of motivation, specifically on the four components of the subjective task value—intrinsic value, utility value, attainment value, and perceived cost. Also assessed was motivation for continued engagement with school-based citizen science (which we term *Future Affinity*).

For the purposes of the current study, a customized Likert-type questionnaire was created, partly based on known expectancy-value questionnaires (Eccles & Wigfield, 1995; Flake et al., 2015; Knekta & Eklöf, 2015; Perez et al., 2014; Vernadakis et al., 2014; Xiang et al., 2013). Online Resource 2 maps questions used in the current study to indices and to sample questions from previous questionnaires. All questions, except for those targeting intrinsic value, used a 7-point two sides scale ranging from *Very Low* to *Very High* (for example, the question for assessing future affinity was phrased as "Given the constraints you are currently facing, to what extent would you be willing to get involved in future school-based citizen science projects?"). For intrinsic value, affective responses were assessed using a 6-point scale and a set of icons instead of textual anchors, consistent with the sources for these questions. For each of the four components of the subjective task value, as well as the future affinity, answers to 1–3 questions were processed and scaled to calculate a numeric index in the range of 1–7.

Coding of value-related statements

To investigate participants' perceptions of the utility and attainment values more closely, statements regarding cost and value were identified in the think-aloud transcripts. A coding rubric was developed to identify expressions of either a positive or a lack of value to one of three possible recipients—teachers, scientists or students. Definitions in the rubric were based on Eccles and Wigfield (2020). Utility value was defined as actual or expected benefits that advance a recipient's present or future goals or plans, and included, for students, effects on current or future knowledge and abilities. Attainment value was defined as actual or expected benefits that strengthen the recipient's sense of identity or allows the recipient to express qualities and behaviors that are perceived as central to one's own personality and self-identity. For students, this definition included effects on their beliefs towards themselves or towards relationships between themselves and their environment. The complete rubric is available in Online Resource 3.

Out of 173 value-related statements, 45 were used for development and review of the rubric by three coders. Then, to test coding reliability, two groups of 45 and 42 statements were coded independently by the researcher that developed the rubric, and by two independent coders who were not part of the review process, achieving 84% and 86% agreement. The rest of the statements, 41 that remained, were coded by one researcher. Table 2 presents some coding examples.

Table 2 Sample coding of utility and attainment values in participants' value-related think-aloud statements

Statement	Type of value	Value recipient	Score[a]
[Teacher:] The professional support I got from the scientists taught me a lot	Utility	Teachers	1
[Scientist:] The project has the potential to contribute to the research but we are not there yet	Utility	Scientists	0
[Teacher:] The project benefits students because they are exposed to an off-curriculum subject that is very relevant to their education	Utility	Students	1
[Teacher:] The project enhances my motivation to lead my team	Attainment	Teachers	1
[Scientist:] Educating is an important act for me, sometimes more than research	Attainment	Scientists	1
[Teacher:] The students will realize that they can take an active part in research without being scientists	Attainment	Students	1

[a] 0 means 'no value', 1 means 'positive value'

Table 3 Mapping of data sources and analysis methods

Data source	Analysis method	Application
Each participant's ranking of 15 motivational items	Hierarchical clustering algorithm for grouping participants that provided similar rankings, and motivational items that received similar rankings	Identifying motivational items highly supported by participants (Table 4) Profiling participants based on their rankings (Fig. 2)
90 motivational think-aloud statements, verbally expressed by participants while filling the questionnaire	Bottom-up thematic analysis for identifying key motivational categories supported by participants	Identifying motivational themes supported by participants, corroborating and expanding findings from the clustering analysis (Fig. 3)
Each participant's responses to a series of 7-point Likert-type questions relating to components of the EVT framework	Calculation of five indices per participant, based on responses to questions related to each index: Future Affinity, Intrinsic Value, Utility Value, Attainment Value, and Cost	Identifying costs and types of values that potentially affect participants' motivation for continued engagement with school-based citizen science (Figs. 4, 5)
173 value-related think-aloud statements, verbally expressed by participants while filling the questionnaire	Coding of each statement according to a rubric, to identify participants' perceptions of the type of value that students, teachers, and scientists derive from their involvement (for utility and attainment values only)	Distinguishing between types of value that various partners stand to gain from their involvement, according to participants' perceptions (Fig. 6)

Summary of data sources and analysis methods

For added clarity of our methodology, Table 3 summarizes the data sources used in this study, their prospective analysis methods, and how we applied analyzed data.

Results

Motivations to engage in school-based citizen science

Analysis of data for RQ1 establishes that student-centered objectives are major motivational drivers for all participants, both teachers and scientists. Scientific goals are supported by a majority of the scientists and several of the teachers, yet to a lesser degree than educational goals. As depicted in the following findings, this conclusion is backed by both clustering of motivation rankings as well as coding of think-aloud statements.

Student-centered motivation items were highly ranked by both teachers and scientists

Participants ranked a predetermined list of 15 motivation items according to personal importance (considering *"how important is this for me?"*). The items were divided into four motivational themes—Educational, Scientific, Societal and Personal (see the Methodology chapter for details). Following clustering of the data, two main motivation clusters emerged, codenamed "Student-centered" and "Science-centered + Personal". The former contains motivation items that apply to students, while the latter is a mix of scientific, societal and personal items. Table 4 presents the list of motivation items, divided to the two clusters. Within each cluster, items are ordered according to the median of ranks given to each item by all participants.

As seen in Table 4, motivation items from the student-centered cluster were ranked higher (medians in the range of 3.5–7.5), demonstrating that both teachers and scientists considered them to be highly important. Scientific motivations were generally ranked lower by both groups (medians in the range of 8.5–12), yet slightly higher by scientists than by teachers. Personal motivations were among those most consistently ranked as least important. Societal items were divided between the two motivation clusters and received diverse ranks, indicating that participants did not view these items as a coherent group.

Participants span across a continuum of education-oriented to research-orientated motivations

To better profile participants according to their motivation rankings, we examined clustering results in the form of a heatmap (Fig. 2). Participants in the two leftmost participant clusters, C1 and C2, assigned high ranks predominantly to the student-centered and educational motivation items (e.g., items #1 and #6, which refer to learning methods and styles). In clusters C4 and C5, high rankings were assigned to science-centered motivation items (such as #8) and in a few cases to a professional development incentive (#12). In these latter clusters, student-centered motivation items were also highly ranked yet the emphasis

Table 4 Median ranks of motivation items

Motivation Cluster	Item No. [a]	Motivation Item	Motivation Theme [b]	Medians of Ranks [c]		
				All Participants	Teachers Only (n=9)	Scientists Only (n=9)
Student-centered	3	Promote certain perceptions or values among the students, or entice them to take action on a certain issue	Educational/Societal	3.5	3	5
	6	Promote meaningful, relevant and authentic learning for the students	Educational	4	2	6
	7	Strengthen students' understanding, knowledge and skills (e.g., in the research subject, in science at general, in other subjects)	Educational	4	3	7
	5	Promote students' appreciation of science (e.g., their interest or trust in science, motivation for a scientific occupation)	Educational/Scientific	4.5	4	5
	4	Enable students and their communities to initiate studies and actions that answer scientific questions or challenges (e.g., cope with a local problem, engage with socio-scientific issues)	Societal	5	5	4
	1	Diversify and enrich school-based learning (e.g., in regard to learning methods, spaces, topics)	Educational	6.5	3	8
	2	Encourage a flow of knowledge from students and their communities to the scientists (e.g., allow students to present their ideas or provide feedback on the research)	Societal	7.5	8	7
Science-centered + Personal	8	Advance existing scientific knowledge within the research domain (e.g., make new discoveries, support existing conclusions and theories)	Scientific	8.5	9	7
	9	Enable students and their communities to influence research processes and the advancement of science (democratization of science)	Societal	8.5	9	8
	10	Advance the scientific study (e.g., meet data collection goals, receive grants)	Scientific	9.5	10	8
	13	Diversify and enrich my professional or personal activities	Personal	11.5	11	12
	14	Satisfy my interest and curiosity	Personal	11.5	13	10
	11	Diversify and enrich the scientific study (e.g., open the research to new directions)	Scientific	12	12	10
	15	Expand scientists' viewpoint on students and their communities (e.g., get familiarized with their attitudes, identify connections between the research and their world)	Societal	12	12	12
	12	Promote myself professionally (e.g., expand my professional expertise, get credit for my involvement)	Personal	14	14	13

[a] Item numbers correspond to the numbers presented later on the left of Figure 2 and facilitate the interpretation of that figure.

[b] Rows are colored by their original motivational theme:
☐ Educational   ☐ Societal   ☐ Scientific   ☐ Personal

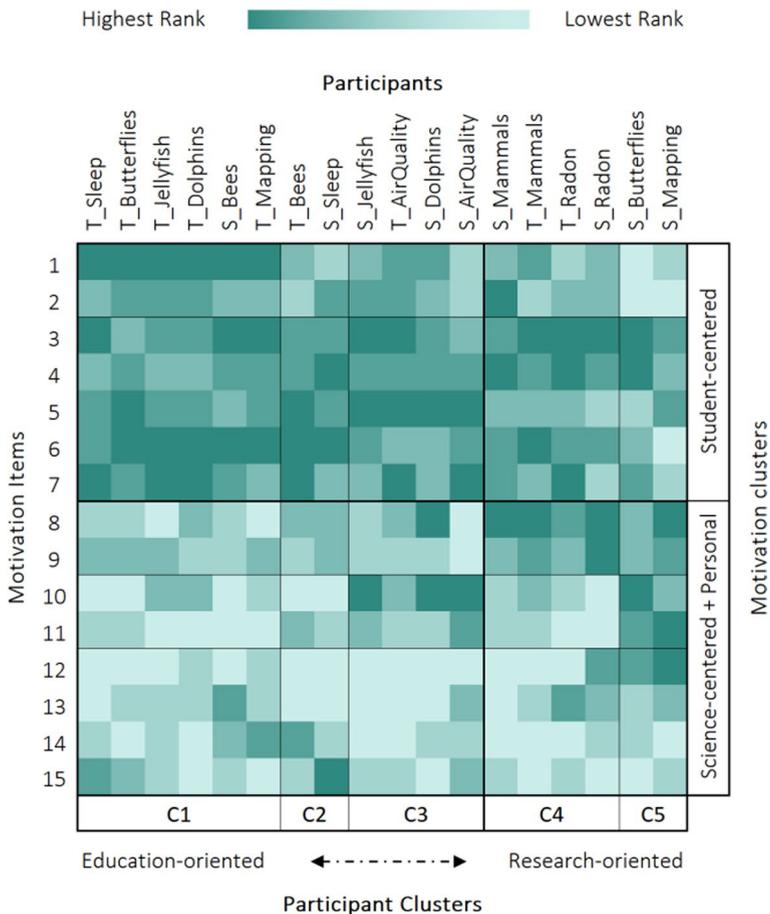[c] Highest rank (most important) is 1, lowest rank (least important) is 15.

Fig. 2 Rank-based clustering of motivations and study participants, presented as a heatmap. Rows and their numberings correspond to the motivation items listed in Table 4. Columns correspond to the teachers and scientists that participated in the study (T—Teacher, S—Scientist). Dark-colored squares mark the highest ranks, with a gradient falling towards the low ranks. Bold lines mark the division between 1st level clusters. Thin lines mark 2nd and some 3rd level clusters

was on different motivational items, giving more weight to societal impacts (such as items #3 and #4).

These findings place participant clusters along a conceived continuum ranging from education-oriented clusters to research-oriented ones (see Fig. 2). As might have been anticipated, education-oriented participants tend to be teachers (6 of 8 participants in clusters C1 and C2), while research-oriented participants tend to be scientists (4 of 6 in clusters C4 and C5). Nevertheless, it is noteworthy that both groups of participants span across the entire continuum. This diversity among participants of the same group may be traced down to individual differences, as well as other possible factors. For example, the education-oriented scientists, from the Bees and Sleep projects, are the most senior among the group career-wise, while the least senior are research-oriented (see Table 1 in the Methodology chapter for more details about the participants). Although this is a very small sample, a
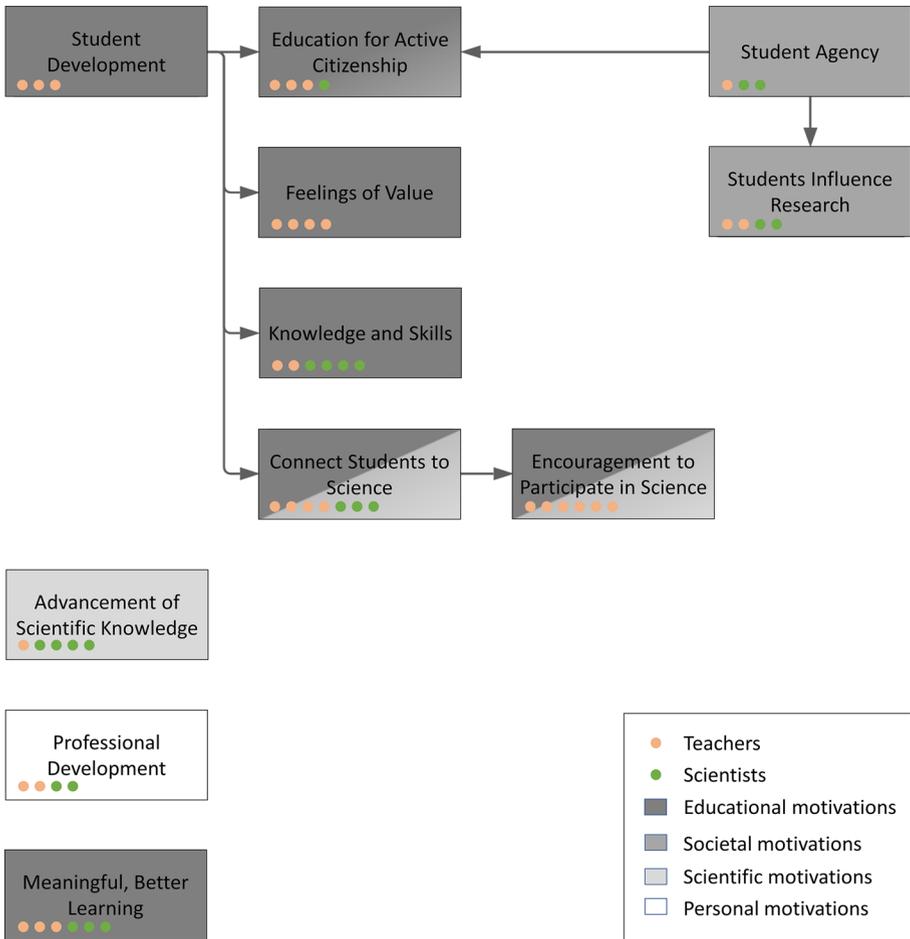
Fig. 3 Coding of participants' motivation-related think-aloud statements. Categories derived from bottom-up thematic analysis of participants' motivation-related think-aloud statements, color-coded by the four original motivational themes. Dots signify the number of teachers (orange) and scientists (green) that made statements pertaining to each category. Only categories related to statements made by at least four participants are shown, together with their parent categories (a total of 11 out of 19 categories found by the analysis)

trend is hinted at in which scientists' motivations for school-based citizen science are correlated with age or career-related factors.

Teachers emphasize students' empowerment and participation in science

To learn more about participants' motivations and to verify findings from the motivation ranking, motivation-related think-aloud statements were coded in a bottom-up thematic analysis to reveal main motivational categories participants chose to address (Fig. 3). Student development categories were the most common, upholding findings from the ranking analysis. In the societal domain, the main objective expressed by participants

was student agency. Scientists addressed the importance of both scientific and educational goals. Some of them have explained the educational rationale, as in:

> My children are already out of school, but I might have grandchildren someday, so I do want to make a difference. It's important to me that schools change. (Scientist of the Sleep project)

Consistent with previously reported results (Kaplan Mintz et al., 2021; Kountoupes & Oberhauser, 2008; Lipshitz et al., 2021, see the Theoretic Background Chapter), teachers often emphasized aspects of student empowerment, more so than other educational goals. These include categories such as *Education for Active Citizenship*, *Feelings of Value* and *Encouragement to Participate in Science*. The latter category emerged from statements made by the majority of teacher participants (6 out of 9). It relates both to students' scientific identity as well as their acquaintance with the scientific world. For example:

> It's important to me to show my students that science is a living, breathing, creative and groundbreaking thing, and that they have a place taking part in that. (Teacher of the Radon project)

> Students have a picture in their head of how science is done, and it was important to me that they see there are also other kinds of science, and if they don't fancy laboratory experiments, they have other ways in which they can still do science. (Teacher of the Sleep project).

Costs and benefits derived from participation in school-based citizen science

Analysis of perceived costs and benefits (RQ2) demonstrates that teachers regard students as principal beneficiaries of the projects while deriving high intrinsic, utility and attainment values for themselves. Scientists mostly emphasize intrinsic and attainment values, with a lower appreciation of utility value.

Perceived high benefits may explain prevalent ongoing motivation for school-based citizen science

The expectancy-value theory (EVT) of motivation was used to analyze the benefits and costs teachers and scientists derive from the collaborations. Indices were calculated for components of the subject task value—*Intrinsic*, *Utility* and *Attainment Values*, and the perceived *Cost*, as well as willingness to participate in future partnerships (aliased *Future Affinity*). Findings are summarized in Fig. 4.

Nearly all participants reported high intrinsic values. Utility and attainment values were generally high for teachers, medium-to-high for scientists. These results may explain the high future affinity indices, all ranged from slightly-high to very-high for 17 of the 18 participants. In the sole case of the Air Quality scientist, perceived benefits were low, as well as the future affinity.

To better discern possible effects of the EVT components on participants' future affinity for school-based citizen science, we took a closer look at each component.
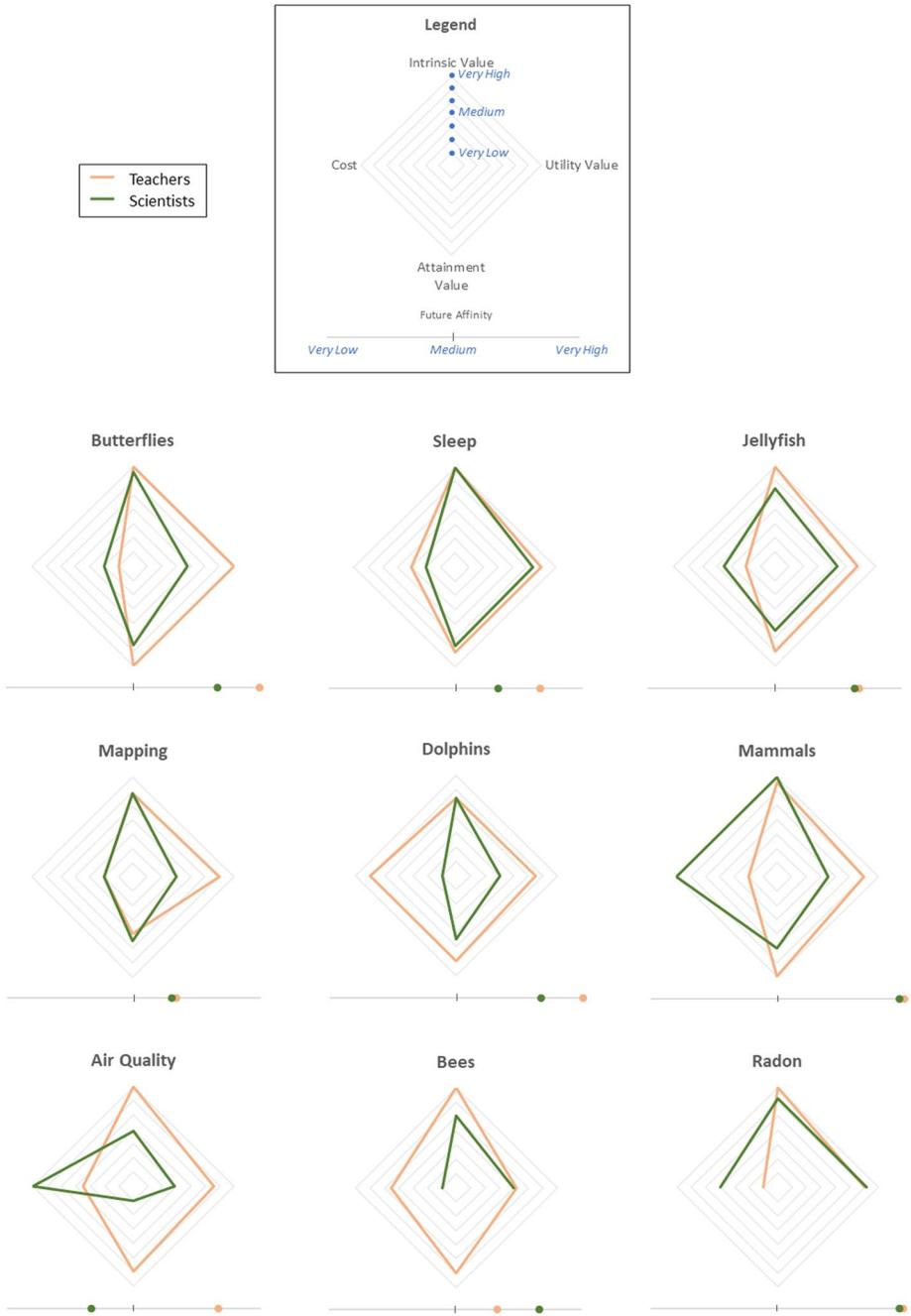
Fig. 4 EVT-related indices for each of the participants, arranged by projects. Indices for intrinsic value, utility value, attainment value, and cost are shown on a web-like graph, where each of the four variables is represented by an axis that starts in the center of the graph and ends in one of the vertices. Below each graph, dots on a continuous axis mark indices for future affinity. The data is shown for pairs of teachers and scientists that collaborated in a mutual project. In three cases, data for attainment value is missing
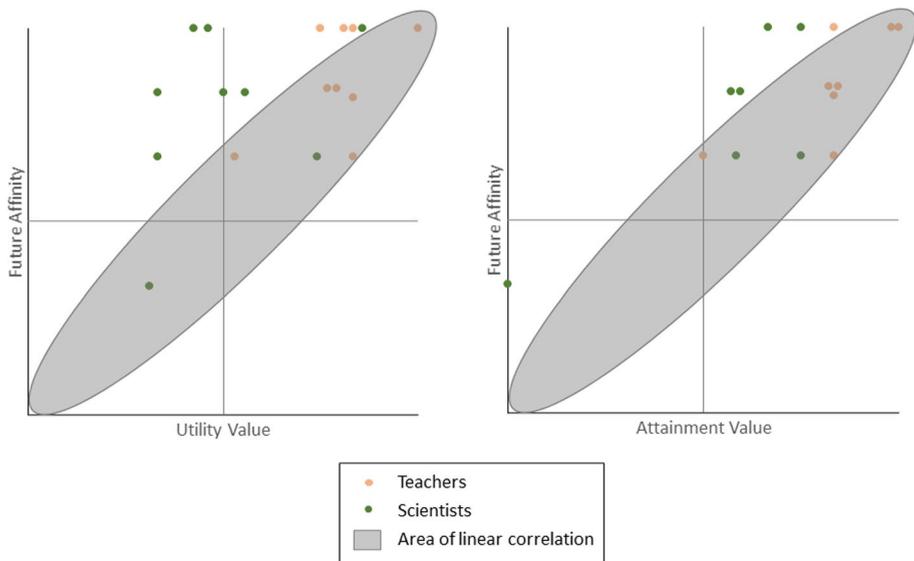
Fig. 5 Participants' future affinity for school-based citizen science plotted in relation to their perceived utility and attainment values. Plot of participants' future affinity against the indices for the utility (left) and attainment (right) values. Orange dots show data for teachers, green dots for scientists. The grey overlay marks the area of a theoretical linear correlation between the variables

Cost of participation does not have a strong effect on future affinity

Study participants from both groups generally reported the cost to be low-to-medium. In three cases the cost was particularly high: the scientists from the Air quality and Mammals projects, and the teacher from the Dolphins project. As mentioned above, only the Air Quality scientist reported a low future affinity. These results suggest that the perceived cost of taking part in the partnerships is not a driving factor in the decision of a large majority of the participants to do so. That is, both scientists and teachers are willing to invest considerable time and resources in school-based citizen science.

Participants' cost-related think-aloud statements exemplify types of costs perceived as bothersome. Generally, participants were concerned by the allocation of time and effort on behalf of the project, e.g.:

> I have many places to be in, a lot of commitments, and time management is very important. (Scientist of the Jellyfish project)

In a few select cases participants provided other reasons, such as:

> In citizen science the questions I can ask are less accurate and more generic and it is difficult to reach high impact journals… No doubt that all the labor I put in [the project] inhibits my work as a professional researcher. (Scientist of the Mammals project).
> I have many tasks and the load [in my work] is high. Ultimately, the system demands 'normal' [student] evaluation methods. (Teacher of the Mapping project)
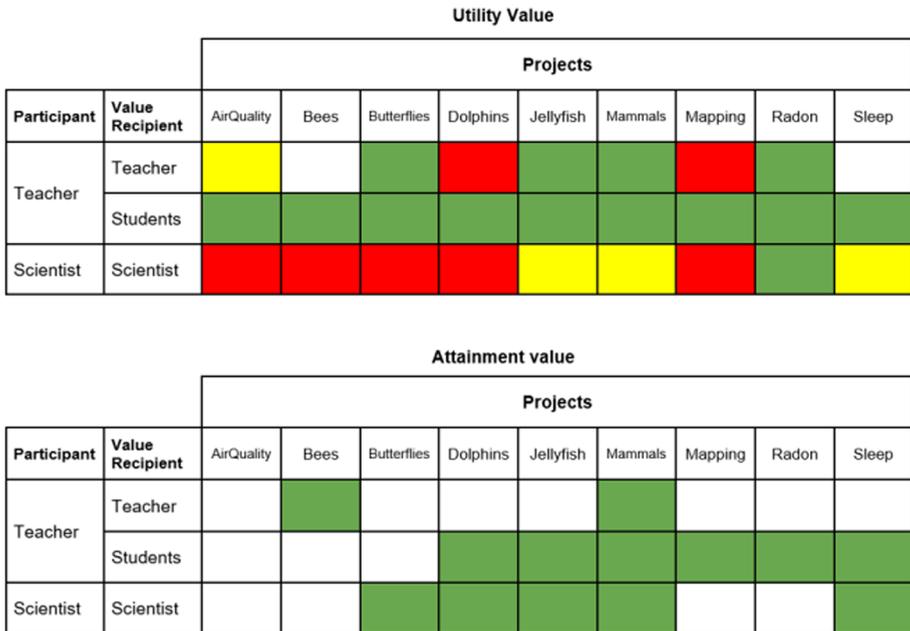
Utility Value

Participant	Value Recipient	AirQuality	Bees	Butterflies	Dolphins	Jellyfish	Mammals	Mapping	Radon	Sleep
Teacher	Teacher	Yellow	White	Green	Red	Green	Green	Red	Green	White
	Students	Green	Green	Green	Green	Green	White	White	Green	Green
Scientist	Scientist	Red	Red	Red	Red	Yellow	Yellow	Red	Green	Yellow

Attainment value

Participant	Value Recipient	AirQuality	Bees	Butterflies	Dolphins	Jellyfish	Mammals	Mapping	Radon	Sleep
Teacher	Teacher	White	Green	White	White	White	Green	White	White	White
	Students	White	White	White	Green	Green	Green	Green	Green	Green
Scientist	Scientist	White	White	Green	Green	Green	Green	White	White	Green

Fig. 6 Coding of utility and attainment values in participants' think-aloud statements. Coding of participants' statements regarding utility and attainment values. Green denotes statements that expressed a positive value, red—the lack of value. Yellow denotes statements of a mixed type (expressing both positive and lack of value). White is shown where no statements were made regarding the particular type of value

Attainment values for scientists are higher than utility values and more closely linked to future affinity

Considering the high intrinsic values reported by most of the participants, we focused our attention on the utility and attainment values and their possible link to ongoing motivation for school-based citizen science. Each was plotted against the future affinity index (Fig. 5).

The plots suggest that for scientists, attainment value might provide a better explanation than the utility value for future participation. To strengthen this conclusion, made on behalf of a low number of cases, participants' value-related think-aloud statements were coded for both value types. The coding scheme reflected the expression of either a positive or a lack of value to a certain recipient (Fig. 6). Teachers and students were regarded as separate recipients since many of the teachers have made that distinction themselves, e.g.:

> I don't think the project benefited me at all. It benefited my students, that's what counts. (Teacher of the Dolphins project)

This analysis demonstrates that scientists express positive attainment gains more readily than utility ones, further strengthening the conclusion that attainment (identity-related) value may be more closely linked to future affinity. That is, scientists related their continued participation to identity-based benefits, more so than utility-oriented ones. The most common statement given by scientists for a lack of utility value was insufficient data collection, while other statements related to the lack of career development opportunities. Positive utility values were associated with expressions of significant data collection by

students and the school community or other ways in which they contributed to promote aspects of the research, such as:

> [Our activity in schools] changed something in the research and in our approach, in our ability to say that we've done that and had that experience. That is something that contributes to the project. (Scientist of the Jellyfish project).
> From the data that students collect it is possible to ask additional research questions and reach future research routes. (Scientist of the Sleep project)

Scientists' expressions of positive attainment values were, in general, related to the citizen science project's educational and societal impacts. This coincides well with findings from the motivation ranking analysis, which determined that scientists place a high value on student-centered motivations. For example:

> Citizen science in schools is one aspect [of the research] who's direct contribution to data collection is not high. On the other hand, the opportunity and the privilege to educate, to empower, and to disperse essential knowledge, definitely provides it with a more than mediocre importance (Scientist of the Jellyfish project).

> An important part of my motivation as a researcher is to drive changes in society in the context of sustainability and conservation. Working with children and youth is an important part of that. (Scientist of the Butterflies project).

Teachers view students as major beneficiaries of the projects

The coding of utility and attainment values establishes that teachers view students as major beneficiaries of the projects, with a positive utility value mentioned by all teachers and attainment value by most (see Fig. 6). Student utility values were related to gaining knowledge and skills, and to the enrichment in experiences and exposure to new opportunities. For example:

> Participating in the project was very beneficial to my students. It provided things that are difficult to provide in schools like relevance, exposure to current affairs, demonstration of a practical use to their studies. (Teacher of the Mapping project).

Attainment values for the students included effects on students' sense of identity or on how they perceive relations between themselves and the world (see coding definitions in the Methodology chapter). For example:

> The students understand that research is something that they can do too. (Teacher of the Jellyfish project)

> For the students, [the project] opened a huge window. They see [mammalian] footprints everywhere they go, not just during classes. (Teacher of the Mammals project)

Several teachers reported a positive effect on their own professional development, while others specifically stated there was none. Other utility values referred to the teacher's status in school and to the fulfillment of curricula goals. Two teachers referred to a personal attainment value, e.g.:

> [By participating in the project] I can contribute to a domain that I strongly believe to be important. (Teacher of the Bees project)

There were a few cases in which beneficiaries other than the teachers, scientists, and students were mentioned (data not shown). These included the general public as a beneficiary of the citizen science project itself, the school community, which was actively involved in one project or stood to gain from students' involvement in another, and the schools themselves, mentioned as gaining reputation or utilizing the project to fulfill other goals.

Discussion

In pursuit of mutual benefits

Our findings show that student-centered motivations were highly supported by both teachers and scientists. The dominance of student-centered motivations may be explained by the school-based context and by the fact that participating scientists chose to take part in school-based projects, sometimes actively seeking this partnership. Teachers greatly appreciated the projects' educational value and the opportunity they hold for advancing teaching and learning in their classrooms. Scientists' main focus was on promoting students' appreciation of science and engagement with science, in regard to either the scientific discipline or to specific research domains. On a broad level, these findings are in accordance with previous studies of teachers in school-based citizen science (Benichou et al., 2022; Kaplan Mintz et al., 2021; Kountoupes & Oberhauser, 2008; Lipshitz et al., 2021) and of scientists' approach towards public engagement which tends to concentrate on educational aspects (Besley & Nisbet, 2013; Golumbic et al., 2016; Riesch & Potter, 2014). In contrast to educational goals and student-centered outcomes, our findings indicate that scientific goals and scientists' benefits were not comparably met. Scientific motivations were significantly supported only by a low number of teachers, and not even by all scientists. Scientists often emphasized other impacts over a direct contribution to their research. They mostly enjoyed their involvement in the projects, and in some cases, considered them to fulfill a personal educational agenda.

The apparent imbalance between student-centered goals and scientific ones, as showcased collectively by both teacher and scientist participants, raise important questions regarding mutual benefits in similar partnerships. How far should partnerships go in foregrounding student-centered objectives? Is accentuation of scientists' attainment-level expectations enough for sustaining partnerships? We offer our stand on this matter, informed both by our personal convictions as well as by findings obtained in this study.

First, it is important to note that in light of the formal educational context, a student-centered perspective is inevitable. However, we believe that diminishing scientific goals in school-based citizen science undermines not just the premise of mutual benefits, but also prospective student-centered outcomes. It is thus desirable that teachers and scientists be both aware of scientific goals and cooperative in their pursuit. Considering our profiling of participants based on motivation rankings (see Fig. 2), it seems that the research-oriented profile, consisting of participants that support both student-centered and scientific motivations, provides a good basis for a mutualistic partnership. Interestingly, this profile coincided with a particular group of scientist participants characterized by age and career stage—the graduate students and untenured faculty (no special characteristics were identified for the teachers in this profile). Whether this is incidental or not, one lesson learned is the importance of identifying partners' background and paying attention to where their expectations from the partnership are coming from (i.e., their underlying motivational
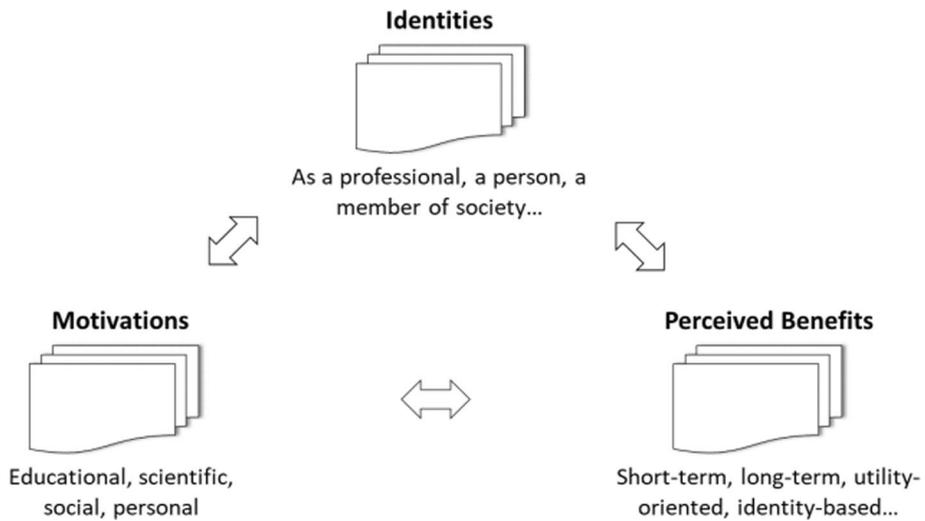
Identities

As a professional, a person, a
member of society...

Motivations

Educational, scientific,
social, personal

Perceived Benefits

Short-term, long-term, utility-
oriented, identity-based...

Fig. 7 A model of the relationships between identities, motivations and perceived benefits within teachers and scientists participating in school-based citizen science

profile). Equally important is the development of processes that can shift expectations or create new ones, in cases where existing stands impede the overarching goal of mutual benefits.

We now return to the theoretical question posed in the Research Rationale section, where we described two opposing views of the concept of mutual benefits. One, which is more prominent in citizen science literature, considers a range of different types of benefits. The other narrows acceptable benefits to include only ones that are directly utilizable for the individual. We do not wish to choose one over the other, nor do we believe such a choice is called for. We rather seek to reveal and resolve the apparent tension between the two. Our findings show that many of the benefits perceived by scientists are related to their individual and social identities, regardless of expected utilizable outcomes. A singular view of benefits does not seem to fully fit teachers as well, as they tend to combine their own individuality with expectations towards cognitive and emotional empowerment of their students. A few of the participating teachers communicated aspects of their own identity that align with their engagement in citizen science (i.e., expressions of attainment value or personal interest). Teachers expressed a layered view of benefits for students, with an emphasis on the potential of citizen science to expand students' perceptions regarding themselves and science. This multifaceted perception of benefits for participating scientists, teachers and students echoes findings from previous studies that describe multiple dimensions through which citizens engage with citizen science projects (Jennett et al., 2016; Phillips et al., 2019). Still, such findings were not previously shown in a school-based context, juxtaposing teachers and scientists that collaborated in shared projects. This methodological setup provides insights at the partnership level, facilitating the examination of the notion of mutual benefits. The analytic approach links motivations with perceived benefits and reveals an underlying interaction between multiple identities that reside within individuals.

It thus seems that teachers and scientists framed their involvement in the partnerships through multiple lenses, of which performing high quality research or achieving certain

student outcomes is only one facet, and not always the most dominant one. Other motivations seem to coincide with the desire to educate, to elicit social change, to innovate schools, and more. The concept of "utilizable benefits" does not suffice for making sense of all these motivations, except as one facet of a wider ecological identity. Thus, we propose that a first step towards constructing a merged epistemological framework for thinking about mutual benefits in citizen science is to consider the interplay between sets of identities, motivations and perceived benefits within participating individuals (Fig. 7). We argue that adopting and operationalizing such a model would increase robustness and sustainability of citizen science projects.

Implications for design of school-based citizen science projects

As individuals cultivate a tangled set of goals, such as both utility-oriented and identity-based ones, citizen science projects can and should be prepared to answer these multiple levels of expectations. We offer initial suggestions for designing school-based citizen science projects that involve teacher-scientist partnerships, based on the insights of this study. The principal point we aim to maintain is the recruitment and addressment of multiple motivations for participating stakeholders. We encourage school-based citizen science designers and implementers to consider how educational, scientific, societal and personal aspects of the project can be made clear and negotiated, allowing participants to connect with perspectives of the project that are important to them while taking into account considerations brought forth by the other stakeholders. Most importantly, design and enactment of the project should strive towards awareness to and ultimately the fulfillment of multiple *types* of benefits, including educational, scientific, societal and personal outcomes.

Doing so is far from a clear-cut task. A crucial step in any project is the translation of strategic plans and goals into an operable scheme. In school-based citizen science, this means turning educational, scientific, social and personal goals into an actionable plan that is *both* a research *as well as* a learning arena. This is a complex process whose depiction is beyond the scope of this article (see for example, Benichou et al., 2022). However, clearly required are communication strategies and capacities that can bridge over disparate views of the project that different participants might possess. This realization brings to light the role that educational researchers can play in supporting the design and enactment of these partnerships using established frameworks for implementing innovations in schools. One such promising framework is that of research-practice partnerships (Coburn & Penuel, 2016), which are long-term collaborations established between educational practitioners and researchers that aim to advance both schools and educational research. School-based citizen science partnerships, apart of their aim of advancing science, are in many ways similar to research-practice partnerships. Both bring together partners from different institutional backgrounds and differing expertise, and require partners to step outside their usual frame of mind and share responsibilities towards accomplishing multiple goals. Drawing on extensive educational research, the research-practice partnership framework offers practical design principles (Kali et al., 2018) and assessment guidelines (Henrick et al., 2017).

While adapting insights from the research-practice partnership framework to a school-based citizen science context seems like a considerable step forward, the unique characteristics of citizen science partnerships needs to be taken into consideration. In school-based citizen science, scientist partners would be less familiar with school systems. Their research usually comes from more alien domains and is not concerned with gaining educational knowledge. Partners' underlying motivations may cover a broad range of objectives and gains, as shown

in this study. Therefore, special consideration should be given to design tools that can help partners spell out more clearly and transparently their own dispositions, motivations, and expectations.

Limitations of the study and future research directions

The main limitation of this study is its reliance on case studies rather than a comprehensive examination of school-based citizen science projects. Additionally, cases included in the study pertain to partnerships at the beginning stages, only 1–2 years in operation. Longer running partnerships may reach more stable relationships, and their examination can produce different results. That said, since this study contends with the challenges of mutual benefits, we believe it was crucial to examine projects at their instigation and as they are struggling with this very issue.

A second limitation is the focus given to personal perspectives of teachers and scientists as an explanatory factor for sustainability of the partnerships. The study does not address important, extra-personal factors such as participants' social connections, partnerships' practices and routines, or the institutional arenas partnerships are embedded in. Such a web of partnership elements can be more clearly examined using existing lenses such as the Multilevel Boundary Crossing framework (Akkerman & Bruining, 2016), which describes processes within school-based partnerships on institutional, interpersonal, and intrapersonal levels. Thus, this study discusses its central issues from one aspect out of several that are applicable, offering a basis for future studies that may uncover connections within and among multiple levels of observation.

Future studies of school-based citizen science partnerships that wish to adopt the expectancy-value theory perspective can benefit from expansions to the questionnaire developed in this study specifically for this purpose. Perceived costs may be examined more closely, replacing the single index used in this study with a distinction between effort, opportunity and psychological cost (Perez et al., 2014). Additionally, it can be interesting to examine the construct of Expectancy, which was not referred to in this study. Expectancy-focused studies may investigate, for instance, how teachers' and scientists' perceptions of their own *ability* to engage in these partnerships may affect their motivation to do so.

Much is left to learn about the interactions between identities, motivations and perceived benefits in citizen science. This article offered a few first steps on what to notice and aim for, yet this is clearly not enough. Expanding beyond the measurement of student learning outcomes and evaluating school-based citizen science as a relational partnership between multiple stakeholders, advances the field's understanding of citizen science enacted in and out of schools. In a future article we intend to examine an additional element that has consequential bearings within partnerships. Both in and out of schools, citizen science grapples with questions regarding power relations and inclusiveness (Dhillon, 2017; Eleta et al., 2019; Haklay, 2018; Hoover, 2016; Liboiron, 2019; Senabre Hidalgo et al., 2021). We believe that elucidating the link between manifestations of power and the issues discussed in this article would further advance understanding of citizen science partnership dynamics.

Conclusion

The overarching practical goal that this study pursues is to promote school participation in citizen science. This will open new opportunities for schools to benefit from the widespread and expanding distribution of citizen science projects, and enable teachers, scientists, and students to connect to their self-perceived identity as active and leading members of society. In this article we outlined two apparently contradicting views of mutual benefits and argued that the tension between them leads to difficulties in establishing mutualistic citizen science partnerships. Our findings point to an interplay between multiple identities of participating individuals and the surfacing of multiple motivations and perceptions of benefits. By staying attentive to motivational components of different types and levels, citizen science projects can strengthen the long-term engagement of participating individuals. When it comes to teachers and scientists in citizen science, it may be possible to bridge over the differences between the two factions by identifying a congruence of identities and addressing common causes. Adding to the growing citizen science literature that regards school-based citizen science as a sub-genre of its own, this study offers new perspectives and methods for examining the applicability and sustainability of such projects.

Declarations

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