

Article

Science Beyond School: Exploring Students' Understanding of Science Through a Citizen Science Project on Micrometeorites

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Abstract

While fostering an informed understanding of science is a key educational aim, students often hold simplified, fact-based views of science due to limitations in traditional pedagogy, materials, and resources. Out-of-school learning environments, such as natural history museums (NHMs) and citizen science projects, offer opportunities to deepen scientific understanding by providing authentic insights into scientific work. This study examines how participation in a short-term citizen science project on micrometeorites, conducted in collaboration with a NHM, contributes to students' understanding of science. Two cohorts of 10th-grade students in an elective STEM course combined classroom learning with museum-based lab experiences to identify and analyze real micrometeorites. Qualitative interviews with students and their teacher revealed that participants gained insight into real scientific work, viewed science as a participatory process, and benefited from self-directed, hands-on learning, including innovative remote access to research instruments. The teacher also emphasized access to lab equipment and authentic research as key benefits, but noted organizational and structural challenges to its implementation, as well as format-specific considerations. The findings highlight the value of school–museum collaboration for promoting citizen science approaches for young people and call for greater institutional support to enable such initiatives more frequently and at a larger scale.

Keywords: nature of science; citizen science; scientific literacy; micrometeorites; natural history museums

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1. Introduction

In an increasingly complex and digitally interconnected world, a robust understanding of scientific thinking and practice is essential for informed personal decision-making and active participation in democratic discourse. Scientific literacy is no longer a niche skill, but a core component of general education with wide-reaching implications for navigating socio-scientific issues, resisting misinformation, and engaging responsibly with emerging (digital) technologies (Dawson et al., 2024; Feinstein & Waddington, 2020; Gandolfi, 2024; Howell & Brossard, 2021). In the literature, scientific literacy is widely regarded as a central goal of science education and refers to individuals' ability to engage with scientific knowledge, practices, and evidence in order to make informed decisions in personal and societal contexts

(Bybee, 1997; OECD, 2019). Beyond the acquisition of scientific facts, scientific literacy encompasses an understanding of how scientific knowledge is generated, validated, and communicated. Within this broader framework, understanding of science constitutes a key component of scientific literacy. It includes not only conceptual knowledge and familiarity with scientific methods, but also an understanding of the epistemic foundations of science, namely, how scientific knowledge is constructed and justified. This epistemic dimension is most commonly conceptualized as the Nature of Science (NOS).

Recent educational research emphasizes that beyond factual knowledge, learners must develop the capacity to evaluate evidence, reason under uncertainty, and understand the NOS as a dynamic, socially embedded enterprise (Dawson et al., 2024). The NOS is highlighted as a core element of scientific literacy, as it enables learners to critically evaluate scientific claims and to understand science as a dynamic, human endeavor rather than a fixed body of facts (Lederman & Lederman, 2014). Consequently, scientific literacy can be understood as an overarching educational goal that integrates content knowledge, scientific practices, and an informed understanding of the NOS (see Figure 1). As an epistemological core of the understanding of science, the NOS is therefore essential for fostering scientifically literate citizens capable of reflective and responsible engagement with science in everyday life (Bybee, 1997). Yet, despite the broad consensus on the importance of the NOS, both its conceptualization and assessment remain highly debated within the research (Hodson & Wong, 2014; Osborne, 2017) and several alternatives to the original version of the NOS have been proposed. As a result, more research is required to assess how learners themselves articulate and negotiate understandings of science and which contextual factors and approaches might shape these interpretations.

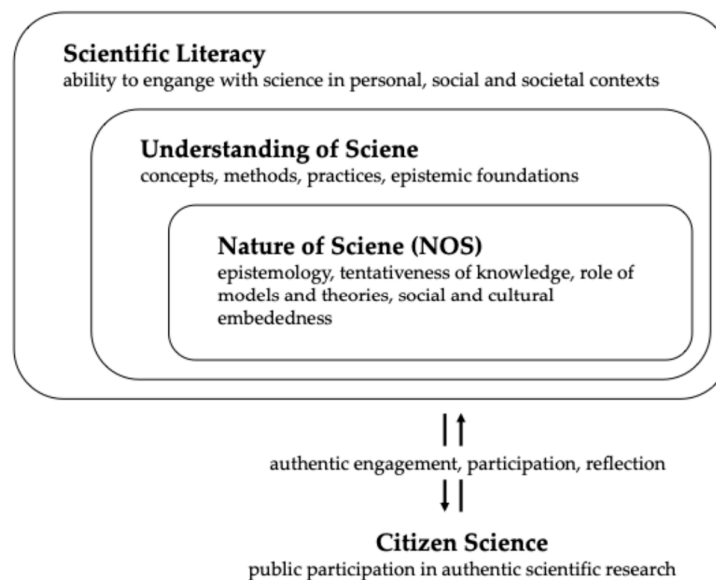


Figure 1. Conceptual framework illustrating the relationship between scientific literacy, understanding of science, the NOS and citizen science. Scientific literacy represents the overarching educational goal. Understanding of science forms a central component, with the NOS providing the epistemological foundation. Citizen science is depicted as an authentic participatory opportunity that can support the development of scientific literacy and understanding of science through engagement in research practices, reflection on evidence, and experiential learning.

Research shows that students often have a simplified, fact-based perception of science, neglecting its process-oriented and creative aspects (Khishfe, 2017, 2023; Lederman &

Lederman, 2014). Several factors hinder the effective integration of the NOS in classroom teaching, including teachers' own misconceptions of it (Lederman, 2007), as well as the use of textbooks as a primary teaching material, which often fail to represent science as a dynamic, iterative process (Bergqvist & Chang Rundgren, 2017; Öberg et al., 2022). To address these challenges, numerous studies have emphasized that instruction about the NOS must go beyond implicit exposure (e.g., Abd-El-Khalick et al., 1998; Khishfe & Abd-El-Khalick, 2002; McComas et al., 2020). Effective NOS teaching requires an explicit focus, opportunities for learner reflection, and ideally, contextualized learning experiences (e.g., Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Schwartz et al., 2004).

Out-of-school learning environments, such as science museums, natural history museums (NHMs), and research institutions, can significantly contribute to fostering an informed understanding of science, including the NOS (Kisiel, 2014; Mujtaba et al., 2018). As authentic scientific environments they can help counteract the misconception that science is merely a static body of knowledge by exposing learners to the actual practices of science. Namely, the methods, tools, discussions, failures, and ethical dimensions that characterize scientific work as a dynamic, socially embedded enterprise involving hypothesis generation, experimentation, peer review, uncertainty, and revision. Many informal settings provide rich learning contexts and offer engaging opportunities for learners to interact directly with scientific objects and exhibits (Reiss & McComas, 2020). However, similar to formal learning environments, learning about the NOS in informal settings or through self-directed experiences must be intentionally designed and supported in order to be effective (Sandoval, 2005).

Although schools and NHMs differ significantly in structure and function, they share a common goal: to provide meaningful, enriching educational experiences. When these two institutions collaborate, they bring together the strengths of both formal and informal learning environments. For such partnerships to be truly effective, they must be built on clearly defined expectations and a strong mutual understanding, with both sides committed to open communication and active cooperation (Osterman & Sheppard, 2010; Wishart & Triggs, 2010). Additionally, evidence suggests that a well-integrated sequence of post-visit activities enables students to construct and reconstruct their personal understanding of scientific concepts and principles presented in the museum—at times aligning with scientifically accepted understandings, and at other times in unexpected and surprising ways (Anderson et al., 2000). Thus, when carefully planned by teachers and museum staff, pre- and post-visit activities present a critical venue for epistemological development. However, despite the great potential that collaborations between schools and museums offer for creating rich learning opportunities in the sciences, there is limited evidence documenting the effects of such interactions or the mechanisms necessary to establish and sustain their success (Kisiel, 2014).

In addition to the potential of museums to make a significant contribution to learning about the NOS, citizen science projects also offer valuable opportunities to gain a deeper understanding of scientific practices. Citizen science means the active involvement of non-professional participants in scientific research tasks such as data collection, analysis, and interpretation (Bonney et al., 2009a, 2009b). Citizen science has been increasingly recognized not only for its contributions to scientific data and research capacity, but also for its educational potential in promoting scientific literacy among participants. Empirical and review studies show that participation in citizen science can influence lay participants' understanding of science, including their grasp of specific scientific concepts, the NOS, and attitudes toward science, all of which are core facets of scientific literacy as mentioned above (e.g., Aristeidou & Herodotou, 2020; see Figure 1).

By engaging with real-world problems and scientific techniques, participants develop a more nuanced understanding of how scientific knowledge is generated and contested. In doing so, they strengthen the skills, attitudes, and values essential for navigating contemporary socio-scientific challenges. Thus, citizen science holds significant potential for formal

education. When adapted for classroom use, citizen science allows students not only to apply scientific methods, but also to participate in authentic research processes (Berndt & Nitz, 2023). This active engagement fosters a deeper understanding of scientific inquiry and enhances one's sense of motivation, identification, and agency within science (Aristeidou & Herodotou, 2020; Berndt & Nitz, 2023; Bonney et al., 2009b). Growing evidence indicates that participants in citizen science acquire knowledge about science and its processes, and that such projects also raise public awareness of science and the diversity of research (Bonney et al., 2016). Projects that integrate students into real data collection and analysis—such as biodiversity monitoring, air quality assessments, or astronomy surveys—have been shown to increase content knowledge, epistemological awareness, and even students' sense of contributing to something meaningful (Saunders et al., 2018; Williams et al., 2021). Research also shows that students who engage in citizen science often shift their perception of science—from a set of static facts to a collaborative, problem-solving activity that is situated in real-life contexts and uncertainty (Bonney et al., 2016; Masters et al., 2016). Importantly, these projects promote not only cognitive learning outcomes, but also civic and environmental responsibility, as students begin to see science as a tool for understanding and improving their communities (Ballard et al., 2017). Thus, integrating citizen science into school contexts offers a dual benefit: it supports curriculum-based learning while also cultivating the dispositions necessary for active scientific citizenship.

Despite the promising educational potential of citizen science (Aristeidou & Herodotou, 2020; Bonney et al., 2016; Solé et al., 2024), empirical research remains limited regarding its specific impact on students' scientific understanding within formal school settings (Williams et al., 2021). Collaborations between schools, NHMs, and citizen science initiatives offer a valuable opportunity to address this gap by engaging students in authentic, inquiry-based scientific practices. These formats combine theoretical instruction with hands-on research experiences, allowing students to not only understand scientific concepts, but also to engage directly in scientific reasoning and investigation (Bonney et al., 2016; Solé et al., 2024). However, such collaborations often face structural, logistical, and institutional challenges, i.e., time, resources, alignment between teachers and/or curriculum and museum offerings, all of which can limit their long-term viability (McCreedy & Dierking, 2013; Pedretti & Iannini, 2020). To ensure broader and more consistent access to authentic scientific experiences, it is essential to explore how citizen science can be sustainably embedded into formal education and meet curricular goals, while also preserving the participatory and investigative character of science (Berndt & Nitz, 2023). The project presented in this article responds directly to these challenges. It introduces a citizen science initiative focused on micrometeorites—tiny cosmic particles that can be found amongst the dust on rooftops—and is designed to facilitate interdisciplinary teaching within the geosciences to deepen students' engagement and understanding of Earth-related phenomena. Anchored between a NHM and secondary school, the project aims to provide students with authentic insights into scientific work and foster their understanding of science as a dynamic and process-oriented enterprise. At the same time, this study investigates the structural and pedagogical conditions under which collaboration between schools and museums can succeed, and how such cooperation can support the development of scientific literacy.

1.1. Research Questions

This study is guided by the following research questions:

1. How does participation in a short-term citizen science project about micrometeorites contribute to students' understanding of science?
2. What opportunities and challenges does a citizen approach about micrometeorites present for collaborations between schools and science museums?

1.2. Citizen Science Project “Micrometeorites”

The idea of developing a citizen science approach to the study of micrometeorites collected in urban areas of Germany was developed by Thilo Hasse in 2018. Searching for micrometeorites on rooftops in Berlin, Hasse (2020) contacted relevant nearby research institutions to help confirm his findings’ extraterrestrial origin. His methods for collection and identification, however, were based on the pioneer work of the Norwegian artist Jon Larsen (e.g., Larsen, 2017), who started searching for micrometeorites in urban areas as a citizen scientist himself about 20 years ago and eventually succeeded in gaining recognition within the established scientific community specialized on meteorites (Genge et al., 2017). 40,000 tons of cosmic dust hit the Earth’s atmosphere each year (Love & Brownlee, 1993). In most cases the dust particles melt by frictional heating during atmospheric entry, with less than 10% landing on the Earth’s surface (and on rooftops in urban areas) as solidified spherules of only 0.2 mm diameter on average, called micrometeorites. The study of urban micrometeorites generally involves several steps as listed below (see also Larsen, 2017, 2019):

1. Selection of a suitable roof top and sampling of dust, often using a magnetic device since most micrometeorites are magnetic;
2. Washing, removal of floating organics and separation by grain size via sieving to facilitate optical identification of micrometeorites;
3. Manual separation (picking) of micrometeorites based on their optical properties under the stereo microscope;
4. Further classification and verification of the micrometeorites by means of a scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectroscopy (EDS) detector to allow for chemical analysis;
5. Several other very specialized micro-analytical investigations may follow depending on research questions, often not suitable for citizen science;
6. Scientific publication in a broad sense (e.g., open access database, reports, publications in scientific journals) of the findings and new insights into urban micrometeorite research.

In 2019 the Museum für Naturkunde Berlin (MfN) in cooperation with Thilo Hasse, a citizen scientist and Ralf Milke, a mineralogist at the Freie Universität Berlin, initiated a pilot project to test if micrometeorite research served as an appropriate field for citizen science (Hecht et al., 2021). Participants represented a wide range of ages and city districts, and after a short introduction, many were able to identify and separate out cosmic material for further investigation with the help of stereo microscopes. Based on this experience, searching for real, yet tiny meteorites appeared to be an enormous attraction and fascination for most people, including students. In addition, the origin and formation of micrometeorites present a suitable topic to foster various scientific fields and interdisciplinary approaches in school education, including physics, chemistry, Earth and planetary sciences (Hecht et al., 2021) and even biology (origin of water and the emergence of life). For example, the process of physical and chemical changes in a single cosmic dust grain during atmospheric entry resembles the formation and early development of planetary bodies in our solar system.

Best practice citizen science projects aim to involve and engage citizens as much as possible into the complete scientific process (Bonney et al., 2016). However, this is often not possible, for example due to no or very limited access to necessary analytical instruments required for sample-related science projects. Overcoming these limitations therefore requires innovative solutions, such as using remote access to laboratory instruments (see Table 1).

Table 1. Overview of project sessions.

Session	Setting	Content
1	School	• Lecture on minerals, rocks and the rock cycle • Lab on identification of minerals, rocks, and ores using MfN tool boxes
2	School	• Lecture on the origin and formation of micrometeorites • Lab on optical properties of micrometeorites using stereo microscopes and prepared samples
3	School	• Lecture on properties and classification of micrometeorites • Lab on identification and picking of micrometeorites under the stereo microscope using research samples
4	MfN Berlin	• Lecture on meteorites and application of polarization microscopy • Lab picking micrometeorites from research samples and investigation of thin sections of meteorites using polarization microscopy • Guided tour to the microanalytical labs of the MfN and introduction to the scanning electron microscope (SEM) that will be used in following session
5	School	• Investigation of the student-selected micrometeorites (from previous session) with the SEM in the classroom via remote access
6	School	• Preparation of a mock scientific poster in small groups, including literature research, data evaluation and visualization, text writing and poster layout • In parallel: interviews with students and teacher

Sessions 1, 2, 3, 5, and 6 were 90 min and Session 4 was about 4 h (including a lunch break).

2. Materials and Methods

The data presented here are part of an ongoing larger survey measuring the scientific understanding of 10th-grade students participating in a short-term citizen science project on urban micrometeorites. In addition to interviews, the NOS questionnaire by Urhahne et al. (2008) was also used; but will be focus of a separate publication. All instruments and questions were presented in the same order. Only data sources directly related to the research questions of the present study are discussed. Therefore, the quantitative data on the students' understanding of the NOS are not evaluated and presented here, as they have a different focus and require a larger dataset.

2.1. Study Design

This study is based on a Design-Based Research (DBR) approach, a methodological framework that emphasizes the close connection between educational research and practice. DBR aims to design, implement, and systematically study educational innovations in real-world learning contexts (Anderson & Shattuck, 2012). In accordance with this approach, the learning environment was co-designed and iteratively refined in collaboration with teachers, museum staff, and researchers from different disciplines. The study was conducted in multiple cycles, each involving planning, implementation, evaluation, and revision. This iterative process enabled both the generation of practical insights for instructional design and the development of theoretical understanding of learning processes in STEM (Science, Technology, Engineering and Mathematics) education. The DBR approach thus supports a nuanced understanding of complex educational phenomena and contributes to the development of sustainable educational practices.

2.2. Project Team

The interdisciplinary project team from the MfN consisted of scientists and student assistants, comprising a total of five members. The scientists included experts in Earth and planetary sciences (including meteorites) as well as educational researchers. The student assistants came from diverse academic backgrounds, including both the geosciences and the social sciences.

2.3. School Collaboration

For this project, we collaborated with a secondary school (Gymnasium) in Berlin. Prior to implementation, the school administration was contacted to assess the school's general interest in cooperating with the MfN and participating in a citizen science project on micrometeorites. After consulting with the teaching staff, the school administration approved the collaboration and facilitated contact with two interested science teachers.

The museum staff then met with the teachers to present the citizen science initiative and outline the project goals. It became clear during these meetings that although the topic of micrometeorites is not explicitly included in the school's curriculum, there are many connections to existing content in both physics and chemistry classes. The teachers suggested which classes and course formats would be particularly well suited for collaboration. The school offers weekly elective science courses (Wahlpflichtkurse) in the 10th grade. In the first project year, students from an elective physics course participated in the project; in the second year, students from an elective chemistry course participated. The same teacher, who teaches both subjects, was involved in both project cycles.

During a preparatory meeting, the number of available teaching hours for participation in the citizen science project was jointly discussed. A schedule was developed to determine on which days museum staff would visit the school and on which days students would come to the MfN (see Table 1). After each session, the project team (museum staff and the teacher) held a brief reflection to discuss what had worked well, what challenges the students had encountered, and which aspects might need to be adjusted in future sessions.

The available time per school year to conduct the citizen science project was limited to a maximum of six sessions of usually 90 min each, with the exception of one visit to the MfN that was organized as a 4-h excursion. The initial two steps of urban micrometeorite research (see Section 1.2), roof sampling and sample preparation, were conducted prior to the project's start in order to save time. The focus on steps three through six, however, comprises sufficient tasks and insights to fulfill a specimen-based study in which the students are able to work with real research samples and instruments and create a final mock poster presentation of their results (see Table 1). Since the general school curricula in Berlin (and other parts of Germany) are substantially lacking basic topics of Earth and planetary sciences, a brief introduction was necessary in Session 1. We addressed some basics on the composition and evolution of Earth with a focus on rocks and minerals. The following two sessions prepared the students to understand the origin of micrometeorites and how they can be recognized and separated from sandy samples taken from Berlin roof tops. This work was continued at the one-day visit to the MfN. Apart from picking micrometeorites (see Figure 2a), the students were introduced into major meteorite types using samples supplied by the meteorite collection. Thin sections of some meteorites were studied using a polarization microscope. Finally, students received a guided tour of the SEM laboratory at the MfN to explain this important technique in front of the machine. A SEM produces very high-resolution images of the tiny micrometeorites and visualizes their typical structures (see Figure 3) that are difficult or even impossible to see under the optical stereo microscope. Importantly, the associated microanalytical tool (EDS detector) allows the chemical composition of the whole micrometeorite or even of single minerals within it to be analyzed, a crucial step in verifying the spherule's extraterrestrial origin.

A novel approach in the project is the use of larger research equipment by the students themselves in the classroom via remote access to the MfN's equipment (see Table 1 and Figure 2b). The intention was to involve the school's citizen scientists in the important step of operating a SEM, which usually is impossible or very challenging, as noted in Suttle et al. (2021). Our study benefited from the well-established remote access to the SEM at MfN due to the 2019/2020 Coronavirus lockdown. After loading the SEM with samples, all analytical steps (imaging, chemical measurements and data evaluation) can be carried out by a laptop

connected to the SEM via the internet. The laptop screen at school was then projected so that each student in the classroom was able to follow the analytical procedure performed by their classmates (see Figure 2b). After some time, the operator on the laptop was changed to allow as many students as possible to experience the procedure themselves.



Figure 2. (a) Searching for and picking out micrometeorites using stereo microscopes in Session 4 at the school lab in the MfN; (b) imaging and analyzing micrometeorites in Session 5 in the classroom using remote access to a museum-based SEM. The projection of the SEM computer screen is shown in the right background.

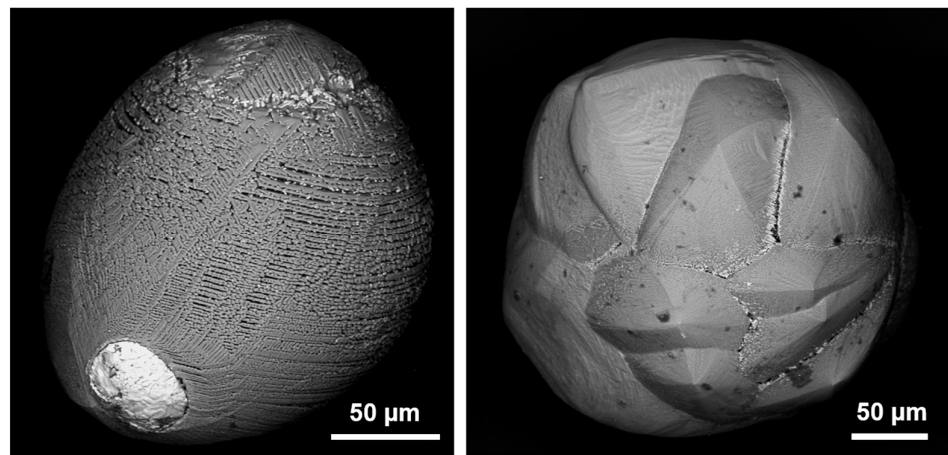


Figure 3. SEM images of two micrometeorites that were discovered by the students during remote control analysis at the classroom.

In Session 6, the most important processes involved in a scientific publication were covered. This included literature research using computers, evaluation of the source's credibility, contextualization of the students' own data in the literature, and presentation of the most important results as text, figures and tables on a poster. The whole process took place in group work, requiring time management by the students, as only 90 min were available.

2.4. Interview Administration

In February 2024 and February 2025, interviews were conducted with students who voluntarily agreed to participate in the study (see Table 1). In addition, an interview was conducted with the course's teacher, who had participated throughout the project. The interviews took place at the school and were conducted individually by two educational researchers, one of whom is a senior scientist with a background in science education

research and the other with a background in social sciences. All interviews were audio-recorded using a digital recording device. By participating in the interviews, both the students and the teacher gave their informed verbal consent for the use and publication of their anonymized data (see Appendix B).

2.5. Research Instruments

To gain deeper insight into students' understanding of science and their perception of the benefits of a citizen science project in science education in school, we conducted interviews using a semi-structured interview guide (see Appendix A.1). In addition to questions related to their views on the NOS, students were also asked to reflect on their experiences in the citizen science project, and to describe how working on the project differed from regular instruction in their elective STEM course and in science classes more generally.

In addition to regular feedback discussions held with the teacher after each session, a final post-project interview was also conducted to further gather his insights (see Appendix A.2).

We also asked the teacher's perspective on students' conception of the NOS and scientific understanding after participating in this citizen science project on micrometeorites.

The full list of interview questions translated from German to English by a member of the project team is provided in Appendix A.

2.6. Sample Characteristics

We conducted interviews with a total of $n = 17$ 10th-grade students (15 to 16 years). Of these, $n = 11$ students participated in the first iteration of the project in February 2024 and were enrolled in the physics elective course, while $n = 6$ students took part in the second iteration during the following school year as part of the chemistry elective course in February 2025. In addition, we interviewed the teacher who taught both student groups in their respective elective STEM courses.

2.7. Data Analysis

The recorded interviews were transcribed and analyzed using qualitative content analysis (Braun & Clarke, 2006; Mayring, 2014). Using MaxQDA, two independent research staff reviewed the transcripts and coded them inductively in line with the research questions according to Mayring's (2014) step-by-step procedure. Numerous codes were initially formulated based on the material. Codes were then revised and synthesized into main themes and corresponding subthemes. Subsequently, all themes and subthemes were finalized through a discursive process, in which the two raters presented their results and reached a consensus when discrepancies occurred to achieve inter-coder agreement. The results, originally analyzed in German, were then translated to English by a member of the project team.

3. Results

To address our research questions, qualitative content analysis was performed to explore the extent to which participation in a short-term citizen science project on micrometeorites contributes to promoting students' understanding of science. In addition, potential opportunities and challenges of implementing such a citizen science project on micrometeorites between a NHM and a school were analyzed. Our main findings are separated between the interviews with students and the teacher in the following section.

3.1. Interviews with the Students

Based on the interviews with the students and the teacher, we were able to identify three main qualitative themes for our first research question. Namely, that participating in a citizen science project on micrometeorites provides insight into real scientific work, the realization that science is a participatory process, and enables self-directed learning and hands-on experience (Table 2). The following section provides illustrative excerpts from the interviews.

Table 2. Overview of the identified themes, sub-themes and the number of students who reported each.

Themes	Subthemes	Students (n)
Insight into Real Scientific Work	First exposure to authentic research	3
	Understanding research cycle and scientific practices	9
Science as a Participatory Process	Science is an iterative process	6
	Accessibility of science participation	5
Hands-On and Self-Directed Learning	Learning by doing	14
	Self-directed learning	11
	Contrast between citizen science project and classroom science	12

3.1.1. Insight into Real Scientific Work

Students reported gaining key insight into the practices and structures of real scientific work as a result of participating in this citizen science project. For a few students, the study served as their first experience engaging with authentic research methods. Student 3021 noted:

For me, I would say that the way of working on scientific projects has changed as a result...I didn't know before the whole project how to work scientifically, how to approach different things. I had absolutely no idea how to conduct research in general. And this has given me a good insight into that now.

Moreover, students emphasized the project's ability to elucidate every step in the research process, from posing a hypothesis and collecting data to analyzing and communicating results. Student 3112 shared, "I saw how this whole process actually is, with the research and then the theory and praxis. So I really grasped the whole process." Similarly, Student 0111 stated, "Now I know a little bit about how scientists structure their research and how they approach certain things. How a publication ultimately comes about too. It is really interesting to learn about that."

Students emphasized the amount of time, precision and documentation required in scientific work. Student 3201 described this aspect:

So for me, well for many, science always seems really far away and always totally complicated and you don't understand it. But the project showed me that even certain small aspects can play a really big role and a great deal of science is also surprisingly mundane.

Similarly, Student 2101 highlighted, "I learned through the project that science is much more precise and detailed, which taught me a great deal about science." Several contrasted this with the simplified and disjointed lessons they typically experience in the classroom, noting that the context of the project allowed for a deeper understanding of research efforts. Student 3111 described this key take-away:

I think I didn't know before how much effort goes into a project like this, because I didn't know that at the end you have to write an analysis or like a result—like

a report about them. In school we started experiments and then made some kind of protocol and then like a brief evaluation and that's it. But now you can see that there is actually a lot more work involved, which I didn't know before.

3.1.2. Science as a Participatory Process

Beyond gaining insight into authentic research structures, some students also developed an understanding of science as an iterative and accessible process open to participation. As a result of their participation, several students described scientific knowledge as not purely applied or transmitted, but generated through observation, experimentation, trial and revision. For example, Student 1101 noted:

At first, I would've thought that you mostly just apply existing knowledge. But through the project, I realized that a lot of knowledge is gained through trying things out so to speak. So I used to think that you derived things from the old, but a lot is also in a way newly created or developed through trial and error.

The hands-on experience throughout the study also shifted some student's perceptions on *who* can contribute meaningfully to scientific inquiry. Having gained insight into the daily tasks supporting scientific work, several respondents linked their participation in the study to a newfound awareness that anyone can participate in science. Student 0111 shared, "You can just basically do science as a civilian if you're just interested and curious. The goal is just to gather knowledge, to ask questions and be able to explain natural phenomena and so on." Student 3101 stated, "Before I thought that only real scientists could really make a difference in science. Now I see things differently in a way that everyone can contribute to science." In this context, Student 2211 also mentioned the trust in science that participating in a citizen science project instills: "I think your goal is to teach us that by doing science, we can gain more trust in it. And that we don't have to be professionals or professors in order to achieve something in science."

3.1.3. Hands-On and Self-Directed Learning

Students consistently highlighted the benefit of hands-on experiences with scientific materials and instruments afforded by this citizen science project. The opportunity to work directly with real samples and research-grade equipment, both inside the classroom and the museum, was described as novel and motivating. Student 3201 found the project "very practical." They continue, "I was pretty much right next to the micrometeorite. The scanning electron microscope too. We were only one meter away and everything got explained to us."

For many respondents, the activities in the citizen science project represented a departure from the primarily theoretical nature of classroom science. Student 0011 described their experience:

Where I really learned a lot was simply in the practical implementation. Like when we went to the natural history museum and started working with the microscopes and also the electron microscope. I'd never seen that before and I also had fun because it was just like a practical application and not always only theoretical, which was a great experience.

By engaging in practical activities, students found complex concepts easier to grasp and more meaningful. They particularly emphasized the independence with which they were able to work on the project:

The practical stuff is really important, that you actually see something and don't just get theoretical facts. So that you don't just get told, 'A micrometeorite is structured like this or that,' but instead you actually pick out a micrometeorite yourself and examine it and then see if it really is one based on what it's chemically made

of. That was really interesting. And I think if you approach it like that, it is actually easier to grasp than if you just learn it theoretically. (Student 0111)

Students also appreciated the ability to discover and explore things for themselves through self-directed learning, like Student 3121:

I understood much better how things work, like, for example with the microscopes. I found that exciting. I felt like a scientist when I used the microscopes. And I thought it was actually really nice that you also had the chance to explore things yourself. And yeah, I really enjoyed it.

Student 3111 shared, “In the micrometeorite project we did our own experiments and, um, were much more independent with the microscopes or tasks where you had to, like, figure things out yourself.”

Many students contrasted the experiential nature of the project with the typical pedagogical approach practiced in the classroom, which. Student 0021 described as, “really just learning formulas or memorization, so nothing scientific.” Student 1101 shared, “There’s this very normal lecture-style teaching, which is pretty uncreative and you also don’t really learn much. And a project like this opens up even more doors, so that you are even more motivated as a student.” Student 0021 similarly remarked:

At school we don’t really do anything with science. I mean, in school you could just explain more how it works, what you do. Because in science classes, we don’t really do anything with science, we just do calculations or something like that...so you could incorporate science more.

In addition, Student 3121 described the benefit of the citizen science project’s focus compared to their classroom science:

I could really immerse myself in the topic and not just do a speed run. And that made it way easier for me, like, really to work longer on one topic instead of working through 50 topics in ten minutes.

As a result, the project offered a more dynamic approach to learning, which participants also associated with greater autonomy. Many reported the value of being able to work independently, explore questions at their own pace and take responsibility for parts of the investigation.

3.2. Interview with the Teacher

3.2.1. Potential of Citizen Science Projects for Scientific Understanding

The teacher believed that participating in the micrometeorite project gave students access to authentic science. Students gained insight into the reality of scientists and their work and were introduced to the necessary people (scientists and their working groups), the premises (labs), and the necessary scientific skills. Indeed, through collaboration between the school and the museum in this citizen science project, students appreciated the museum as a scientific institution. He described:

I actually think, um, probably the main growth is at a meta level, in that they realize in a way that science isn’t something that takes place in some lonely little room, but that there are working groups made up of several people who work on projects, have laboratories, are somehow networked—that there are also museums that conduct research. I think that’s something that very few students know about, and very few people in general.

The students also had the opportunity to use real scientific equipment to which they otherwise would not have access, a key aspect he underscored:

What I found particularly nice for the students was that they simply had the opportunity to work with equipment that they would otherwise not come into

contact with, like, the high-quality stereo microscopes and electron microscopes, which of course is a highlight. These really are devices that students normally have no access to and I think that was almost the most important point.

The teacher also emphasized that participation in a citizen science project has the potential to show students that science is a process in which obstacles are to be expected and perseverance is required. He described this central component:

I think it's also an experience, um, how much hard work goes into science. And that science, if you look at it a bit critically in quotation marks, is not always a big eureka moment, but rather also a lot of painstaking work that is not always fruitful, although we were lucky that we did have success. That is very motivating, but of course we could have been left empty handed, and then they would have had to live with that. So that's another thing. That's also something I allow in my teaching, at least with the older students, that experiments simply don't work sometimes and then they have to live with that.

3.2.2. Challenges and Requirements in Collaboration Between Citizen Science Projects and Schools

Format-Specific Considerations

The teacher believed that it would be more effective to conduct the citizen science project on micrometeorites as a block schedule project, e.g., as a block internship or block seminar, rather than as a weekly double lesson of 90 min, so that the students can immerse themselves in the topic more deeply and are less distracted:

The students come out of it mentally, they have so many other things that somehow come crashing down on them and then it's quite far away again, especially when you do evaluations like this, then many things are already very distant, in terms of time and mentally.

However, he pointed out that this is difficult to implement because the school system does not account for such projects:

The more intensive, the better. So if you can somehow manage to do it as a block internship or block project, that would be ideal. So if you can really manage to do it for a week, 5 days, each 6 or 7 h a day, that would be perfect. It's just the organizational constraints that make it difficult in some circumstances. Most of the time, it's difficult to anchor something like this in the school system.

The teacher believed that citizen science projects, such as the micrometeorite project, open up new opportunities in school and provide students with new insights. However, he also believed that participation in a citizen science project can only ever be an additional offering and therefore can and should not replace regular lessons. He was also certain that participation in a citizen science project is only suitable for those students who are genuinely interested in the subject and thought that implementation in regular science lessons would be basically impossible, as the number of students is too high. He shared:

I think there is virtually no way around a structured science education. But it can be added, especially in the context of such courses like elective courses, where you simply have a bit more freedom in terms of content and where you have particularly interested students, um, that certainly has potential.

However, he added that other citizen science projects that are more accessible and simpler might be more suitable. He considered the citizen science project on micrometeorites to be so specialized that only a certain type of student would be suited to participate:

I don't see the potential in regular lessons, I have to say. I think there might be potential for other projects, other citizen science projects that are perhaps even

more vibrant and more accessible, where there is less hard work involved. Because I would say the average student, who is not so interested in the subject, needs more entertainment.

Compensation for Additional Work

Based on his experience, the teacher responded that he had to spend a lot of extra time preparing for and following up on the citizen science project. He believed that if the school management and administration want citizen science to be integrated into the school, then compensation must be provided for the teachers involved. He suggested that this could take the form of reduced teaching hours:

If schools want something like this to happen regularly and a lot and continuously, then they have to compensate for that. Just realistically speaking, in terms of the amount of work I had to do, I should have actually had an hour's reduction in teaching hours for the whole year.

Another possibility, he suggested, would be to set aside fixed periods of time for collaboration on a citizen science project and to firmly anchor them in the school curriculum:

The resources must be available, in particular time resources for the teachers involved. Because it is simply more work than regular lesson preparation. That is clear. And ideally, time could be made available, but that is really a question of school organization.

Organizational and Legal Factors

Furthermore, in the teacher's opinion, it would be useful to go through the entire research cycle of the citizen science project (see Section 1.2), so that the students are involved in all scientific processes, e.g., collecting samples from rooftops. However, the teacher believed this would not be possible for organizational and legal (i.e., insurance-related) reasons. He stated:

Of course, it would be great to go through the whole work cycle, but then again there are the organizational difficulties. So, starting with the sampling on a roof would of course be optimal. And then to also do the specimen preparation and so on. You'd have to—I don't know, you'd have to think about it thoroughly again, whether you could somehow manage to, uh, I'll say, tie that together organizationally and legally in such a way that it's feasible.

4. Discussion and Limitations

In the following section, we would like to discuss the results in relation to our research questions and present possible implications for the successful practical implementation of citizen science projects in schools. Finally, we discuss the limitations of our study.

4.1. Discussion

In our study, we collaborated with 10th-grade students in a citizen science project on urban micrometeorites connecting scientific research within a NHM to a school setting. This meant that the students not only learned about and participated in a citizen science project, but also gained insight into a research museum. They visited laboratories, conducted scientific work themselves in the museum's microscopy center, and became familiar with the scientists there. In this context, the aims of the study were to investigate the extent to which participation in a short-term citizen science project on micrometeorites could influence the scientific understanding of 10th-grade students and what opportunities and challenges a citizen approach about micrometeorites presents for collaborations between schools and science museums.

Our interviews revealed that the students gained insight into authentic scientific practices at a NHM—an experience that a few described as entirely new. Students reported that they had previously imagined scientific work to be quite different, and that the citizen science project reshaped their perceptions of how science operates in real-world contexts, i.e., research on micrometeorites. The teacher also emphasized that the citizen science project offered students a realistic perspective on scientific work. These findings are consistent with those of Masters et al. (2016), in which participants reported that their participation had given them a new perspective on scientific research. By allowing the students to discover the museum as a place of research during the project, our results also underscore Mujtaba et al.'s (2018) statement that “natural history museums can provide students with new knowledge and perspectives [...] with impacts that can last years” (p. 59). Citizen science is exciting, can lead to a better understanding of scientific content, and sometimes leads to a deeper knowledge of scientific processes and the NOS (Bonney et al., 2016). By examining how students themselves negotiate ideas about the purpose and processes of science beyond predefined NOS dimensions, this study provides empirical insight into learners' situated understandings of science and highlights the potential of inductive qualitative approaches within the contested field of NOS research. The students also mentioned the process of scientific work in their interviews, emphasizing that it consists of several distinct phases. Participation in the project made this process more tangible to them, and they highlighted the insight into scientific publishing as a particularly novel experience.

Due to its short-term design, our study was not able to assess long-term effects on education outcomes as mentioned by Bonney et al. (2009a). However, our results do support previous findings that the form of participation plays a significant role in learning outcomes (cf. Berndt & Nitz, 2023; Bruckermann et al., 2022; Greving et al., 2022). Unlike many other studies—particularly those focusing on biodiversity research—where students or participants are mainly involved in data collection (e.g., Bruckermann et al., 2022; Greving et al., 2022; Mady et al., 2023), the students in our citizen science project were engaged in many scientific processes like data collection, data processing and data analysis as well as publication of a mock scientific poster. However, they were not involved in sample collection on the roofs simply due to safety concerns and time restrictions. Yet, Bruckermann et al. (2022), found that when given the choice, most participants preferred to be involved in data collection rather than in data analysis. Accordingly, we hope to involve students in this step of the process in the future.

A key highlight of the project was the students' use of specialized equipment—such as microscopes or the SEM—via remote access. As a result, students participated directly in the data analysis, an aspect that both students and the teacher emphasized as especially positive and significant. Since analyzing scientific results requires a high degree of abstraction in order to simplify complex ideas and interpret them accordingly, this level of participation is particularly striking (Moormann & Sturm, 2025). Participation in research-related activities that resemble those of scientists therefore provides a context to better understand the development of knowledge about scientific methods and practices, and thereby promotes desired conceptions of the NOS (Schwartz et al., 2004). Integrating scientific research as a context for learning about the NOS appears meaningful and is also reflected in our study. Overall, the results indicate that citizen science projects have the potential to promote basic scientific literacy by giving students direct experiences with the scientific process (Saunders et al., 2018).

Another theme we identified is that by participating in our citizen science project, the students and teacher recognized and emphasized that science is a participatory process. Several students had previously thought that only trained scientists could do science, but after the project, emphasized in the interviews that everyone has the opportunity to participate in science. They therefore recognized the central idea of citizen science (Bonney et

al., 2016; Strasser et al., 2019), a takeaway that is perhaps made more salient by the fact that the practice of collecting micrometeorites from roof dust was originated by a citizen scientist, Larsen (2017).

The data also revealed self-directed learning and hands-on experience as a third main qualitative theme, in which the students emphasized that they enjoyed being active and using equipment such as microscopes and the SEM. Compared to regular science classes, they particularly appreciated exploring and working independently instead of being taught in a traditional classroom setting and primarily memorizing facts and applying formulas. Therefore, this study underscores the value of collaboration between schools and science museums in providing students with meaningful, interactive scientific experiences using research-grade equipment. By enabling students to directly engage with real-world scientific research beyond traditional curricula, the citizen science framework also helped make abstract scientific concepts more tangible through practical exposure.

This leads us to answer our second research question regarding potential opportunities and challenges between schools and science museums for collaborating on a short-term citizen science approach on micrometeorites. In contrast to regular classes, which they described as covering many topics in quick succession, students really appreciated having so much time to focus on the topic of micrometeorites in the project. They also emphasized that the citizen science project made them feel more motivated, a finding that is also evident in other studies (e.g., Berndt & Nitz, 2023; Kelemen-Finan et al., 2018). Berndt and Nitz (2023) found evidence that variables like consistency of participation had a particular positive influence on student motivation. They also found that participants showed lower levels of perceived pressure when participating in a citizen science project at school compared to typical lessons (Berndt & Nitz, 2023).

At this point, we would also like to present and discuss our views and perceptions, i.e., those of the museum team. In agreement with the teacher, we found that the ability to conduct citizen science projects in schools requires some form of compensation or additional staff. One possibility is that scientists receive credits for participating in such projects, so that this activity earns as much merit as traditional scientific research, which is usually recognized in the form of publications. Alternatively, museums or scientific institutions could have additional staff who are responsible for coordinating such projects, since although students, student assistants, and graduates of the voluntary ecological year could provide support, it would be difficult for them to take full responsibility for coordination. One difficulty in implementing citizen science in schools is that the goals of science and formal education do not necessarily coincide (Roche et al., 2020). When citizen science initiatives and schools collaborate, one challenge is finding a balance between scientific and educational goals (Harlin et al., 2018). While projects must address a genuine scientific research question and data quality and quantity must meet scientific standards (Kelemen-Finan et al., 2018), the goals of formal science education must also be fulfilled—namely, to improve students' scientific literacy and to meet additional specific educational objectives aligned with the school curriculum. Therefore, both aims must be equally emphasized in order to ensure a successful and sustainable citizen science project in schools (Zoellick et al., 2012). Although our project is not directly linked to the curriculum, we worked with the teacher in advance to identify many points of connection to the classroom and, in line with the DBR approach, adjustments were made repeatedly throughout the two project phases. Osterman and Shepard (2010) point out that cooperation between schools and museums combine formal and informal aspects that require mutual support. The best results are achieved when the partners jointly establish rules that they both adhere to, starting with a set of agreed expectations, a commitment to get to know each other as well as possible, and an ongoing dialogue in order to improve their joint work. Citizen science could offer a bridge between formal school curricula and out-of-school science learning—from learning about science to learning

through science—as evidenced by the profile of students learning science by acting as scientists identified by Solé et al. (2024). Therefore, challenges such as student motivation, teacher engagement, alignment with the curriculum, and the balance between differing expectations and objectives should be addressed in order to achieve successful initiatives that benefit both science and education (Kloetzer et al., 2021). Integrating citizen science projects into formal school curricula can offer a low threshold entry point to authentic scientific work and extend the reach of museums as sites of participatory science learning.

Future research should more deeply explore how structured cooperation between schools and research museums can bolster STEM education and better integrate citizen science into formal learning environments, particularly to enhance students' reflection on the NOS.

4.2. Practical Implications and Recommendations

In the previous discussion of our research questions, we have already outlined several practical implications, which we will briefly summarize here.

Resources—particularly in the form of (additional) time, personnel or compensation—play a crucial role in both institutions. All parties involved should discuss in advance what time frame the project can realistically have and what level of commitment can be expected from participating teachers, scientists, and other team members. In this context, our project demonstrated that a short-term citizen science initiative can be successfully implemented over six sessions (one session per week, each lasting 90 min in school and one 4-h session at the museum; see Table 1). However, the teacher's suggestion of running a citizen science project in a block format, such as during a dedicated project week, is also a viable and potentially effective approach. Ideally, citizen science should be permanently integrated into the school curriculum and could even become an interdisciplinary subject that supports multiple academic disciplines. However, this remains a vision for the future—one that would require clear support from educational policy. In addition, consideration should be given to how the individuals involved in the citizen science project, such as teachers, scientists, or students, can be compensated or supported by additional personnel. For teachers, this could take the form of reduced teaching hours, while for scientists, participation could be recognized as part of their academic output, for example like a publication of a scientific paper. However, at research NHMs, publishing results in high-ranked peer reviewed journals in the natural sciences still remains the top criteria for evaluation, particularly for young scientists in the fields of bio- and geosciences.

While carrying out the citizen science project, the project team noticed that the school was poorly equipped in terms of equipment, e.g., microscopes and IT. This sometimes led to problems and was very time-consuming when, for example, additional equipment had to be brought to the school. The lack of sufficient equipment is an issue in the majority of schools, and it would therefore be beneficial for schools to have more resources in this regard in the future. Moreover, in advance of citizen science projects, Harlin et al. (2018) recommend that teachers should be supported in finding suitable and efficient projects that meet their immediate teaching needs.

Even though there was close coordination between the project team and the teacher, it would have been desirable and certainly more effective if the entire course had been developed jointly with the teacher. This would have allowed the previous lessons to be geared more effectively towards preparing for the project. This was a wish shared by both sides, and as a result, a joint course in the future is currently under development, in which the citizen science project will take place over a longer period (one semester) and will be prepared jointly with the teacher.

In addition, it may also be useful to contact one of the associations that now exist in many countries (cf. Storksdieck et al., 2016), such as the European Citizen Science Association (ECSA) or the German platform “mit:forschen,” to find out whether there are any

special interest groups that engage with citizen science and schools. This is certainly a good place to gather practical ideas and exchange valuable experiences. ECSA (2015) has also published the “Ten Principles of Citizen Science” in many different languages, which can be helpful in exchanging best practices and building capacity for a citizen science project. However, we recommend that museums and schools intending to carry out a joint citizen science project maintain close communication, regularly evaluate the processes involved, and continuously adapt them. Only through such collaborative and reflective practice can citizen science be successfully and sustainably embedded in school education.

4.3. Limitations

Our study has several limitations. Although we conducted the project over two years, the sample size is very small. The scientists who conducted the interviews were part of the project team and were known to the students and the teacher as such. However, the roles of the various members of the project team were made clear from the outset. Accordingly, it was clear to the interviewees that the two educational scientists were responsible for data collection and were not directly involved in the citizen science project itself. Nevertheless, it cannot be ruled out that the interviewees may have made statements that they considered socially desirable. However, this is no more or less the case than in other interview studies and should be minimized by the clear distribution of roles.

In addition, this is a purely qualitative and exploratory study that provides insights into the subjective and retrospective experiences of the students and teacher participating in this project. As a result, no direct factors for change or stability in epistemological beliefs can be derived from this. The results of the study are not representative, but nevertheless provide a useful approach for collecting the complex experiences and interpretations of the students and analyzing them inductively, particularly with regard to the NOS.

Furthermore, this was a short-term citizen science project in which the students only participated for a total of six sessions. This study reports first results from an ongoing larger survey. It remains to be seen in future studies how longer participation, such as over a school semester, will affect the students’ understanding of science.

Finally, participation could be expanded through future DBR cycles, which would take the form of reflection opportunities for students. For example, students could discuss their individual understanding of science in group discussions, thereby reflecting on their own understanding. With regard to the measurement instruments, the study could be triangulated using additional quantitative NOS instruments. To this end, careful consideration would need to be given to which instruments in the current literature are suitable for assessing outcomes related to epistemological beliefs within the scope of such a study.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and was carried out in accordance with the ethical guidelines of the American Psychological Association (APA). As per the policies of the institutions involved, formal approval by an ethics committee was not required.

Informed Consent Statement: Verbal informed consent was obtained from each student prior to participation in the study. Verbal consent was deemed appropriate for this minimal-risk educational research, conducted under the supervision of teachers and in accordance with institutional and data protection guidelines. A copy of the consent script translated from German is available under Appendix B.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author [A.M. (Alexandra Moormann)]. The data are not publicly available due to containing information that could compromise the privacy of research participants.

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Abbreviations

The following abbreviations are used in this manuscript:

APA	American Psychological Association
ECSA	European Citizen Science Association
EDS	Energy Dispersive Spectroscopy
MfN	Museum für Naturkunde Berlin
NHM	Natural History Museum
NOS	Nature of Science
SEM	Scanning Electron Microscope
STEM	Science, Technology, Engineering, Mathematics

Appendix A

Appendix A.1. Interview Guideline for Student Interviews

1. How has your understanding of what science is changed as a result of the project? (your idea of how science works or what science means—including the goal of science and who carries it out)?
2. To what extent do you think creativity plays a role in science classes (physics, biology, chemistry, math, geography)? (How important do you think creativity/creative thinking is in science lessons?)
3. How do you use creativity when learning in science classes (physics, biology, chemistry, math, geography)? (When must or can you be creative?)
4. When you think of the micrometeorite project, does creativity play a (different) role there than in your science lessons? Explain/justify your answer.
5. What do you think of the following statement: “Scientific theories are often more complicated than they need to be.” Is that true in your opinion? Explain why or why not.
6. Why do you think it is that learning about science (scientific work, processes or procedures, research cycle) is/seems complicated for most people?
 - a. What would help you to make learning about science less complicated? (In reference to the project: What experiences did you have in the micrometeorite project in terms of learning about science? Did the project help you to understand scientific theories and processes more easily? Explain!)

7. What do you think is the purpose of science? (The aim of science, why we actually conduct research)
 - a. And when you think about the project again: What is the purpose of our research in the project, in which you discovered and analyzed new micrometeorites?

Appendix A.2. Interview Guideline for Teacher Interview

1. What motivated you to participate twice in the micrometeorite project with your students—as, so to speak, citizen scientists?
2. What did you particularly like about the project?
3. What do you think the students learned from the project—in terms of the subject matter, but also about what science is and how it works?
 - a. To what extent is such a project suitable for promoting students' understanding of science?
4. What challenges have you faced in order to successfully integrate the micrometeorite project into your class?
5. In your opinion, what conditions must be met for such citizen science projects to succeed in schools? What recommendations would you give us?
6. In your opinion, what opportunities does the use of such citizen science projects in schools offer?
7. Is there anything else you would like to say about the project and collaboration?

Appendix B

Appendix B.1. Verbal Consent Script for Participating Students

As part of our study, we would like to know more about your experiences with the project. There are no right or wrong answers, we just want to know your opinion. You are helping us to better understand how citizen science projects, like the micrometeorite project, are suitable for use in schools.

The participating students will receive a questionnaire before and after taking part in our citizen science project and will then be interviewed in concluding interviews. The questionnaire will be distributed and collected by staff members from the Museum für Naturkunde. The interviews will be conducted by a research associate.

The results of this study will help us understand how citizen science projects in schools can support students' understanding of science.

Your answers will be transcribed and treated anonymously. We will record the interview as an audio file, which will be destroyed after transcription. All data will be anonymized and used exclusively for the purposes of our educational research. Do you have any questions? Based on the description of the study, would you like to participate?

Appendix B.2. Verbal Consent Script for Participating Teacher

Over the past few months, you have carried out the citizen science project on micrometeorites with your class and us. We would now like to ask you a few questions about how you perceived the project. As part of our study, we would like to know more about your experiences with the project. There are no right or wrong answers, we just want to know your opinion. You are helping us to better understand how citizen science projects, like the micrometeorite project, are suitable for use in schools.

The interview will be conducted by a research associate. The results of this study will help us understand how citizen science projects in schools can support students' understanding of science.

Your answers will be transcribed and treated anonymously. We will record the interview as an audio file, which will be destroyed after transcription. All data will be

anonymized and used exclusively for the purposes of our educational research. Do you have any questions? Based on the description of the study, would you like to participate?

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