A JOURNAL BY SISSA MEDIALAB

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PRACTICE INSIGHTS

How can we enable school students to learn and participate in science engagement initiatives? Roles and tasks of enablers

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Abstract

Involving school students in authentic research beyond their school learning means creating participatory, out-of-school opportunities related to research processes, giving them a voice in the applied format of science engagement. Important for such endeavours is a group of people we identify as "enablers". Based on insights from two long-term and large-scale science engagement initiatives in Germany (the Darwin Day science outreach and the Plastic Pirates citizen science program), we identified four principal work tasks of enablers. They are described as (i) aligning the needs, expectations and goals of involved participants, (ii) translating differing conceptions about science into shared visions, (iii) guiding the design of the initiative through educational theory, and (iv) evaluating the success of the out-of-school science engagement initiative. We further suggest that self-awareness of being an enabler, working at the interface of the research and education sphere, is an important prerequisite to successfully collaborate with participants.

Keywords

Citizen science; Science education; Bridging research, practice and teaching

Received: 29th August 2024
Accepted: 14th April 2025
Published: 17th July 2025

1. These authors contributed equally to the manuscript and therefore share first authorship.

1 ▪ Introduction

We are living in an era of need for dialogue and participation in science. The conventional and still widely applied deficit model of science communication does not meet the current requirements, as it is constrained by a unidirectional exchange of knowledge [Seethaler et al., 2019]. Opening and democratizing science requires constant reflection of the roles of people involved [Metcalfe et al., 2022], to ensure that all participants can mutually benefit from the exchange [e.g. Atias, Baram-Tsabari et al., 2023; Roedema et al., 2022]. Numerous formats exist to foster the engagement of the public in research processes, for example interactive lectures, visits by researchers to classrooms or involvement in collaborative research processes such as citizen science. Collectively, and for the purpose of this article, we refer to these formats as "science engagement initiatives" [see Weingart et al., 2021, for a critical discussion of using the engagement rhetoric].

Several complex challenges exist to achieve a meaningful engagement of people in science: different knowledge levels of participants and their varying trust in science [Hendriks et al., 2016], different interests and motivations of researchers to engage in science outreach [Dudo & Besley, 2016], or a lack of ability to reach out to marginalized communities [Dudo et al., 2021] may compromise the overall objectives. Challenges often arise from misaligned goals, interests and expectations of the involved groups: researchers often prioritize the transfer of knowledge [Seethaler et al., 2019], and are rarely trained in techniques to analyse and adapt to different audiences [Claussen et al., 2023; Dudo & Besley, 2016].

To reduce such challenges, intermediaries often take up roles and tasks to facilitate the implementation of science engagement initiatives between the involved participants. These intermediaries can be educational researchers, science communicators, or representatives of community groups addressed by these initiatives [Kimbrell et al., 2022; Kohen & Dori, 2019; Salmon et al., 2021]. In this article, we use the term "enabler" to describe this role.

Enablers play unique roles in science engagement activities taking place in educational contexts involving school students and teachers, where the above-mentioned challenges may be amplified [Atias, Baram-Tsabari et al., 2023]: for example, both the educational and research institutional systems have their own epistemological approaches, which can complicate the process to balance scientific and education goals of science engagement initiatives. Further, contradictory to other science engagement initiatives, participating school students cannot be considered volunteers, emphasizing the need of enablers to consider motivational aspects besides personal interests [Atias, Baram-Tsabari et al., 2023]. Additionally, enablers working in the school context must consider curricular requirements and time constraints.

In this manuscript we suggest that the tasks of enablers in science engagement initiatives in the school context go beyond being communication intermediaries or information brokers [e.g. Kohen & Dori, 2019; Neal et al., 2015]. Based on the "tripartite model" presented by Salmon et al. [2021] for the citizen science context, and adapted to the educational context, we define enablers of science engagement initiatives as people having a profound understanding of (i) a research topic and research community, (ii) the educational sciences and learning processes, as well as (iii) practical experience of applying their knowledge to the school context.

Enablers of science engagement initiatives partake in a range of activities: they enable the adaptation of complex scientific information without becoming trivial [Dudo et al., 2021], consider the interests, expectations and practicalities of all involved participants [Claussen et al., 2023], are a central contact person, and help improve the overall quality of the initiative [Salmon et al., 2021]. However, information on *how* enablers precisely fulfil these tasks are rarely systematically communicated in literature [Atias, Baram-Tsabari et al., 2023; Kimbrell et al., 2022]. In the present analysis, we describe four main work tasks we have identified for enablers of two science engagement initiatives implemented in Germany, the science outreach program Darwin Day and the citizen science program Plastic Pirates.

2 ▪ Characterization of the Darwin Day and Plastic Pirates programs and their participants

The Darwin Day and Plastic Pirates programs address school students and their teachers and aim to better involve these groups in science initiatives. Both programs have existed for many years. They are repeated annually and have addressed thousands of school students (Table 1). As a core part, besides the involvement of the school students, they offer extensive educational materials targeted towards different groups of participants. They are further subjected to regular evaluation and optimization processes and are offered at no costs to the participants.

The Darwin Day is a lecture-based outreach event designed to communicate current research in evolutionary biology and to provide insights into the work of researchers, with the

Table 1. Characteristics of the Darwin Day and the Plastic Pirates science engagement initiatives.

	Darwin Day	*Plastic Pirates*[1]
Target group	School students aged 15 to 19 and their teachers	School students aged 12 years and older and their teachers
Target region	The region of Schleswig-Holstein in Germany	Schools in Germany, located near rivers
Main objectives	Communicating authentic insights into evolutionary biology and the work of researchers	Generating scientific knowledge of plastic pollution and raising scientific literacy and environmental awareness of participants
Format of engagement	School students participate in interactive lectures held by researchers	School students participate in sampling campaigns
Lifetime of program	16 years, established in 2009	10 years, established in 2016
Number of participants	On average approximately 1,200 per year, approximately 20,000 in total	On average approximately 2,000 per year, approximately 24,000 in total
Coordinating institutions	Kiel Evolution Center, Kiel Zoological Museum, Leibniz Institute for Science and Mathematics Education	Kiel Science Outreach Lab (Leibniz Institute for Science and Mathematics Education, Kiel University), Ecologic Institute
Website of program	https://www.kec.uni-kiel.de/outreach/Darwintag.php, in German	https://www.plastic-pirates.eu/en

[1] Since 2020 the Plastic Pirates program has been extended to further other European countries (see https://www.plastic-pirates.eu/en/partners). This article refers to the implementation and resulting insights of the Plastic Pirates in Germany.

goals of broadening students' interest and understanding of science. The annual event features four to five 20-minute lectures followed by a question-and-answer session mediated by an online tool. Since the COVID pandemic, the Darwin Day is being organized as a hybrid event, combining advantages of digital and face-to-face communication by streaming the event to a larger audience, while also enabling direct contact between researchers and school students [Claussen et al., 2023; lectures are available at https://www.youtube.com/watch?v=cbjXPZ351u4, in German]. After the event, further questions by the school students are answered in written form (https://doi.org/10.5281/zenodo.10590292, in German). Subsequently, new lecturers are invited by the program team. This includes a phase of guidance for lecturers to create engaging presentations for the school students and teachers.

The Plastic Pirates program is a citizen science initiative focused on collecting research data, improving scientific literacy, and illustrating how school students can participate in environmental research processes. During sampling campaigns, the school students follow standardized methods to investigate different aspects of litter pollution of rivers, for example the pollution by single-use plastics at riversides [Kiessling et al., 2023] or pollution of floating microplastics [Kiessling et al., 2021]. The school students and teachers work independently during a sampling using the educational materials as guidance. After the active involvement of the school students, each sampling is followed up by close communication between the involved teachers and program coordinators in order to ensure that the students' research output is of high quality [Dittmann et al., 2022]. Each iteration takes approximately nine months, including recruitment and guidance, a two-month sampling campaign, followed by data revision and sharing first results. The publication of research articles based on the school students' findings commonly takes more than two years [Dittmann et al., 2023].

In both programs, four groups of participants were involved: (i) the enablers, as the program coordinators, consisted of interdisciplinary teams of science education researchers, teachers and researchers from the life sciences. They encompassed theoretical and practical knowledge, teaching school students in regular classroom settings as well as extracurricular activities. (ii) Researchers from different disciplines provided input for the programs in cooperation with the enablers. The target group of both programs were (iii) teachers and (iv) school students, with the teachers facilitating their students' learning through the out-of-school programs. As can be seen from the description of the enablers, these roles have fluid boundaries and overlaps exist: for example, most researchers associated with the Plastic Pirates program had out-of-school teaching expertise and classify as enablers, and it could be argued that all teachers are enablers for their school students [Aristeidou et al., 2023]. Similarly, groups of participants involved in science engagement often have overlapping motivations, as they are working towards bridging the research and educational spheres. However, each group's specific motivations influence their focus and tasks within the initiative. For example, enablers are primarily motivated by facilitating understanding, actively negotiating and adapting interactions to meet diverse needs. Researchers may focus on knowledge dissemination and public engagement. Teachers aim to integrate relevant science topics with curriculum requirements, and students may primarily engage to learn and explore within a unique educational setting (Figure 1 and following sections).

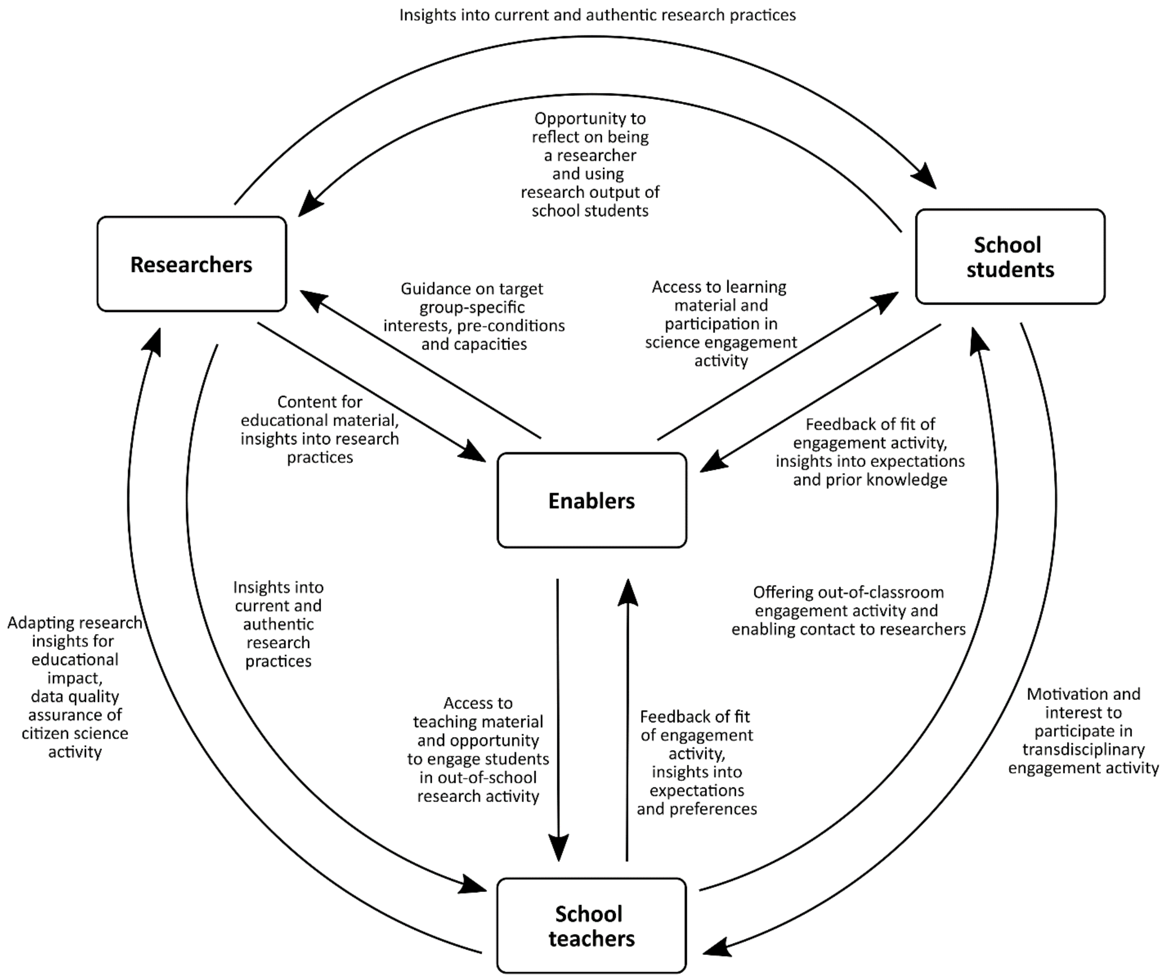

Figure 1. Participants of the Darwin Day and Plastic Pirates science engagement initiatives and interactions between groups.

3 ▪ Four tasks of enablers of science engagement initiatives

The subsequent sections present our generalized insights of four work tasks the enablers of both programs fulfilled. A challenge is stated for each task, followed by an illustration on how enablers of the Darwin Day and Plastic Pirates addressed this challenge.

3.1 ▪ *Enablers align needs, expectations and goals among participants*

A challenge in science engagement initiatives arises from the different needs and expectations of participants, and the differing goals pursued by them within the initiative [Figure 1; Atias, Baram-Tsabari et al., 2023]. While this is normal, an understanding of key challenges faced by participants and aligning overarching goals to the capacities and motivation of participants is an important work task for enablers. This includes regular contact with participants, with the aim to identify and share their needs and expectations and thereby foster a common understanding of what a successful implementation of the program would look like.

For this purpose, workshops were conducted for the Darwin Day, implementing sequential focus groups with the different participants (evolutionary biologists, teachers and school students). Statements of one group were presented to another to evaluate each other's needs, goals and expectations, but also knowledge regarding the content of the lectures and perception of scientific processes and methods of inquiry (i.e. *Nature of Science* aspects; see Cofré et al. [2019]). Results of these focus groups showed that researchers considered it particularly important to convey the novelty, uncertainties and limitations of research work, aspects which school students also found very motivating and interesting [Claussen et al., 2023]. Teachers agreed that this was an important aspect of science, but expressed concerns regarding the complexity for school students and their own insecurities teaching this topic due to the lack of in-depth knowledge. This reciprocal exercise was the basis for the developed educational materials and guidelines of the Darwin Day (https://doi.org/10.5281/zenodo.10590065, in German), which did not only address the school students but also teachers and evolutionary biology researchers (with suggestions regarding their presentations and lectures).

For the Plastic Pirates, a team of plastic pollution researchers and school teachers co-developed the scientific and educational objectives and methods of the program. During this process, each other's needs and expectations were constantly negotiated. This concerned aligning research methods to the capability and motivation of school students. As one result of this process, the investigation of very small plastic particles was excluded from the program as this would have required cumbersome contamination prevention work undertaken by the school students [Kiessling et al., 2021]. The overall result of this process was, similar to the Darwin Day, educational material addressing teachers (containing information of the research topic and work tasks for the classroom, https://doi.org/10.5281/zenodo.7986353) and school students (containing sampling instructions and exercises for reflection of their participation in a research activity; https://doi.org/10.5281/zenodo.7986321). Over the years, iterative changes have been made to the program's materials and communication approaches [Dittmann et al., 2023] to adapt to newly identified needs and expectations.

3.2 ▪ *Enablers translate differing conceptions about science into shared visions*

A further challenge is that participants likely hold different mental concepts related to science and how research works. These concepts could, for example, be specific to the research topic in question, could relate to the nature of scientific work itself or address the overarching goals of initiatives, such as achieving an empowerment of the participating school students regarding their own efficacy as researchers. Closely related to the first task, the enablers work on identifying and translating these differing mental concepts among the participants. Importantly, the identification of mental models of scientific concepts requires trust among all parties, as some may be regarded as misconceptions by other participants.

For the Darwin Day, it became obvious that school students and teachers had differing concepts of the uncertain nature of research. This was identified by asking both groups about independent learning exercises in natural science classes. School students mostly understood that they were supposed to find own approaches to conduct experiments with a pre-determined solution. Teachers had a more open definition, imagining work tasks without a strict framework and correct solutions, therefore imagining to use independent learning in these classes as a proxy to illustrate how actual research work is conducted. As a result of this identified discrepancy, the developed educational material emphasized the changing nature of research work, including how researchers deal with uncertainties, and the necessity to work in interdisciplinary teams in order to obtain solutions for novel research questions.

For the Plastic Pirates an emphasis was placed on offering school students and their teachers the opportunity to engage with the topic of plastic pollution beyond the sampling activity. Results from the predecessor initiative of the Plastic Pirates showed that the researchers and the school students held different perceptions of the mental concept "effectively engaging with environmental problems by conducting research": among participating school students there was no increase in their self-efficacy, i.e. their self-reported capacity to act on the environmental plastic litter problem after participating in the initiative [Kruse et al., 2020]. Researchers, on the other hand, were convinced that school students had effectively engaged on the problem by providing valuable data. Apparently, the school students had not conceived that contributing to research was part of a solution to this problem. Another explanation might be that the school students found their own efficacy dwarfed by their increase in knowledge related to this global, prevalent and ubiquitous environmental problem. The educational material therefore offered ideas for hands-on activities and project-based work to continue engaging with this issue after participation in the sampling activity.

3.3 ▪ *Enablers guide the design of the initiative through educational theory*

A lot of theoretical models exist, attempting to facilitate the public's engagement with sciences, which can be used to refine the educational design of science engagement initiatives. The challenge for enablers lies in identifying a model which fits the scope of their science engagement initiative and adapting it in a way so that the goals of the initiative align with the larger science-society interactions implied by the model. Ideally, this task results in a roadmap for implementing concurrent changes within a science engagement initiative.

For the Darwin Day, a *Nature of Science* model, the *Family Resemblance Approach* [Erduran & Dagher, 2014] helped to communicate a more authentic and diverse picture of science. The *Family Resemblance Approach* considers the research settings in which individual scientists work, for example their goals, knowledge, and applied methods, and sets them into a larger perspective. This perspective encompasses research work ethics and practises as well as collaborative aspects, but also the existent political, institutional and social systems in which research is taking place. This holistic model was chosen to guide the design of educational material of the Darwin Day because a gap between the goals, expectations and mental concepts of different participant groups had been identified. Further, school students showed a high interest in the knowledge acquisition process of research work and the personal motivations of researchers investigating microorganisms.

In the Plastic Pirates program, the *Logic Model for Public Engagement with Science* [AAAS, 2016] played an important conceptual role as it reflected the overall goals of the Plastic Pirates, which as a research program served to encourage school students to actively engage with the environmental crisis caused by plastic pollution. The model is structured to obtain short-term to long-term outcomes. Among the former are portraying research in a more accessible way to members of the general public, for example by focusing on the work done by scientists as individuals. Within sustained programs, these can later translate to long-term outcomes, such as an improved trust between researchers and members of the public or co-creating knowledge so it becomes more relevant to policy makers [AAAS, 2016]. These desired outcomes aligned well with the Plastic Pirates and have been used as guidance, for example by emphasizing the value of the individual research contribution by the school students and transmitting that they become local plastic pollution experts, collecting novel and reliable research data. These messages were intended to serve as motivation to further engage with the plastic pollution topic (with the help of the provided educational material).

3.4 ▪ *Enablers evaluate the success of science engagement initiatives*

Different science engagement initiatives naturally pursue varying goals, for example improving learning of participants, empowering certain target groups, or allowing for reflection of the role of participants in science-societal interactions [Haywood & Besley, 2014; Kloetzer et al., 2021]. Enablers are therefore faced with the challenge to find specific measures for each goal.

For the Darwin Day the primary objective was to enhance the program by fostering deeper cognitive engagement and interactive dialogue with the school students. Focus groups, questionnaires and discussions with school students and teachers participating in the Darwin Day served as principal means to evaluate whether progress towards this goal was achieved. These were conducted iteratively and regularly, accompanying the implemented changes such as more interactive lectures, reserving more time during lectures for dialogue, integrating virtual tools allowing for interaction, and offering further elaborate materials that could be used in the classroom after attending the activity (https://doi.org/10.5281/zenodo.10590292, in German).

For the Plastic Pirates the principal method of evaluation was the peer-review process of studies based on the data collected by the school students (a considerable challenge, given that many citizen science studies remain unpublished; [Theobald et al., 2015]). Data quality considerations are the main concern for many citizen science studies [Balázs et al., 2021], therefore, to be able to pass peer-review, several internal evaluation measures were developed for the Plastic Pirates [Dittmann et al., 2022]. These data quality mechanisms took on a substantial part of program conceptualisation and working time, and were prominently presented in published academic manuscripts based on the school students' findings. This importance was also frequently communicated to the participants through the educational material and communication with teachers [Dittmann et al., 2023].

Science engagement initiatives do not only need to make their impact visible to participants but usually to other stakeholders, such as funders. The Darwin Day and Plastic Pirates programs involved hundreds of participants during each iteration (Table 1), making the success easily recognizable to stakeholders. However, we caution against using participant numbers or publicity as the central or singular measure of success as it distracts from the educational and research goals of these initiatives, which naturally are much harder to assess and require dedicated research questions (and funding) themselves. Importantly, there is also a trade-off between large participant numbers and their depth of involvement within an initiative: the Plastic Pirates are a largely contributory citizen science program, which allowed for large participant numbers compared to more co-created initiatives [Senabre Hidalgo et al., 2021].

4 ▪ Discussion and conclusion

Based on the two presented cases, we derived four tasks of enablers in science engagement initiatives (Figure 2): the first task — aligning needs, expectations and goals among participants — constitutes an assessment of each participant's criteria for successful collaboration. The second task — translating differing mental concepts into a shared vision — contains elements of *Educational Reconstruction* [Duit et al., 2012], as it addresses different perceptions among learners, teachers and, in this case, also researchers. The third task — guiding the design of the initiative through educational theory — refers to the need for grounding science engagement initiatives on insights from educational research (and therefore is comparable to principles of *Design-Based Research*, Enzingmüller and Marzavan [2024] and Obczovsky et al. [2025]). The fourth task — evaluating the success of the initiative — aims at developing methods to track improvements of the science engagement initiative for all participant groups and other stakeholders alike.

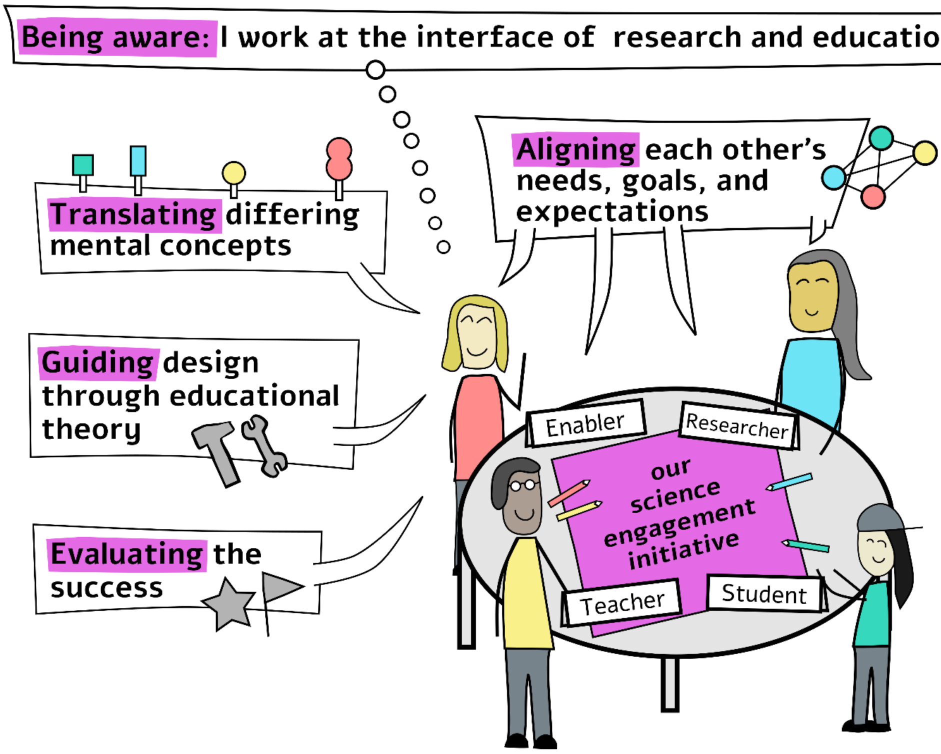

Figure 2. Work tasks of enablers in science engagement initiatives addressing school students.

All tasks were important for unlocking opportunities of collaboration beyond the usual mode of engagement and encouraged ownership of crucial parts of the Darwin Day and Plastic Pirates for the groups of participants. Taking part in collaborative science engagement initiatives therefore presents a unique opportunity for the participants, facilitated by the involved enablers: amongst other benefits, school students can obtain an authentic insight into research practises, often contrasting with how science is portrayed in school [Koomen et al., 2018]. Teachers and researchers can increase their capacity to work in transdisciplinary contexts and on applied projects with societal relevance and an immediate value for the participants [Atias, Kali et al., 2023; Kali et al., 2018].

Previous studies have shown that the role of enablers and their knowledge of science communication and science education are important for engaging people in research, particularly considering school students as a target group [Atias, Baram-Tsabari et al., 2023; Roche et al., 2023; Roedema et al., 2022]. To ensure the success of science engagement initiatives, it is crucial for participants, especially enablers, to understand their role clearly. A prerequisite to engage as an enabler is a self-awareness of being an intermediary between involved groups, to see this work as an integral part of the career [Woitowich et al., 2022], and to receive institutional support to contribute to science engagement [Kimbrell et al., 2022]. Careful thought should be put into communicating roles and associated labels as they may unintentionally cement power imbalances, which dialogue-oriented formats of science engagement seek to minimize [Eitzel et al., 2017; Roche et al., 2023].

In this article, we focused on an institutionalized form of science engagement initiatives; both the Darwin Day and the Plastic Pirates were affiliated with institutions of higher education and relied on funding by government agencies. We explicitly acknowledge the existence and value of community-led, bottom-up, and “uninvited” forms of science engagement initiatives [see for example Mahr & Dickel, 2019, for a discussion of the institutionalization of citizen science] and do not wish to contradict these efforts by implying that the presented findings are universally applicable. Further, we would like to emphasize that the insights presented in this manuscript are largely a result of a reflective analysis of our roles as enablers in two exemplary science engagement programs and are therefore, to some extent, subjective.

The presented work tasks of enablers are interrelated and require close interaction and cooperation among the participants. While some tasks benefit from expertise in specific areas, we argue that all benefit from the insights and experiences of a transdisciplinary team, having theoretical knowledge as well as practical experience implementing science engagement activities in the school context. We explicitly invite enablers and participants of other science engagement initiatives to reflect on the suggested work tasks and insights and recommend evaluating their applicability to other initiatives and fields of science education and outreach (Figure 3).

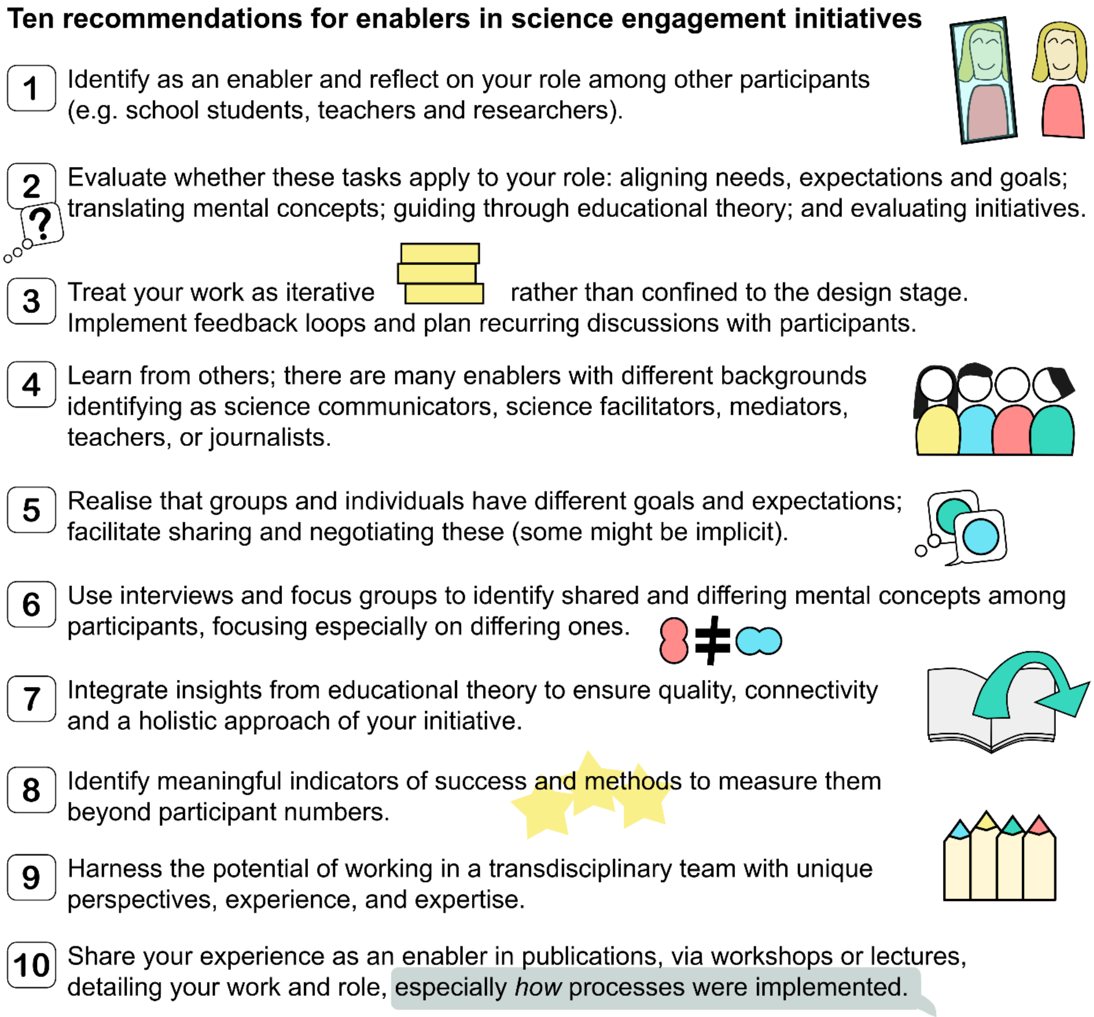

Figure 3. Recommendations for enablers in science engagement initiatives.

Acknowledgments

We are grateful to all school students, teachers and researchers who were involved in the Darwin Day and the Plastic Pirates programs and admire the ambition of many teachers to go the extra mile to offer insights into authentic research processes to their students. We would further like to thank everybody involved in these programs from Kiel Science Outreach Lab, the Leibniz-Institute for Science and Mathematics Education, Kiel University, Justus Liebig University Giessen, the Ecologic Institute, the Científicos de la Basura network, the Plastic Pirates network and the Research Group on Learning and Instruction from Ruhr Universität Bochum, as well as Arden Goodfellow for English-language revision of the manuscript! The manuscript further benefited from valuable comments from two anonymous reviewers and the editor.

Funding statement
Financial support for CC, IP and HS was provided by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) within the CRC 1182 on the 'Origin and Function of Metaorganisms' (Project-ID 261376515; public relations project to IP). The Plastic Pirates in Germany were funded by the German Federal Ministry of Education and Research. TK received funding by Kiel University — "Zukunftsvertrag Studium und Lehre stärken", and the Ocean Frontier Institute's Visiting Fellowship Program 2024, through an award from the Canada First Research Excellence Fund.

Declaration of conflicting interest statement
The authors declare no conflict of interest.

Ethical considerations statement
The authors declare that no ethical approval was required for the research findings presented in this manuscript.

Data availability statement
No data was used for the findings presented in this manuscript. The resources described in this manuscript are available and were linked in the respective manuscript sections. All graphics used in this article are available in an editable format on zenodo: https://doi.org/10.5281/zenodo.13362323.

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How to cite

Kiessling, T., Claussen, C., Kruse, K., Enzingmüller, C., Kremer, K., Knickmeier, K., Dittmann, S., Schulenburg, H. and Parchmann, I. (2025). 'How can we enable school students to learn and participate in science engagement initiatives? Roles and tasks of enablers'. *JCOM* 24(04), N02. https://doi.org/10.22323/148020250716165543.