LEARN CitSci

Enhancing youth learning through Community and Citizen Science: a guide for practitioners

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Contents

(Right) Citizen science enables children to explore, use scientific tools and make a meaningful contribution to research

About this guide

This guide was designed to support practitioners running Community and Citizen Science programmes and similar informal science learning activities. It shares the findings and recommendations of the LEARN CitSci research study, which explored the learning processes and outcomes for young people aged 5–19 years who participated in Community and Citizen Science projects. This guide can be freely distributed in its original form for non-commercial purposes. All content is the copyright of the authors except where specifically stated otherwise, and no images or sections of text can be extracted and used elsewhere without first obtaining permission. This material is based upon work supported under a collaboration between the National Science Foundation (NSF), Wellcome, and the Economic and Social Research Council (ESRC) via a grant from NSF (NSF DRL# 1647276) and a grant from Wellcome with ESRC (Wellcome grant no. 206202/Z/17/Z). Disclaimer: Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of NSF, Wellcome, or ESRC.

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(Left) Young people in Los Angeles document nature in the city through citizen science

> "Young people can be motivated by citizen science as a means to both contribute to and take action on environmental and societal issues they care about. Adult facilitators both new to and experienced with citizen science can find valuable practical advice and insights from the LEARN CitSci research and Guide, with an eye towards equitable, generative experiences designed for youth to thrive as both learners and leaders."

Jennifer Lynn Shirk
Interim Executive Director - Citizen Science Association

The LEARN CitSci research project

LEARN CitSci (the Learning and Environmental Science Agency Research Network for Citizen Science) was an international partnership of Community and Citizen Science practitioners and educational researchers across the UK and USA, led by the Natural History Museum in London and the University of California, Davis. Together, we undertook a five-year research programme to explore the learning processes and outcomes for young people who take part in Community and Citizen Science projects.

This research was funded by Wellcome and the Economic and Social Research Council in the UK and the National Science Foundation in the USA. The funders collaborated to create a unique funding scheme called Science Learning + that specifically aimed to support US-UK partnerships and enable close collaboration between educational researchers and informal science learning practitioners. LEARN CitSci was one of five projects funded through this scheme to undertake interdisciplinary research into youth science learning that could inform and influence practice across the field of informal science education.

The LEARN CitSci project focused on the Community and Citizen Science programmes at three natural history museums: the Natural History Museum in London (NHM London), the California Academy of Sciences (CAS) in San Francisco, and the Natural History Museum of Los Angeles County (NHMLA). These Community and Citizen Science programmes covered a variety of project styles, scales, and settings and therefore provided a lens through which to examine a range of informal science learning activities, which reflected a much broader field of practice. Partnering with the Zooniverse team at the University of Oxford and learning researchers at the University of California, Davis and the Open University UK, we aimed to study three distinct types of Community and Citizen Science projects:

1. **short-term events, such as BioBlitzes,**
2. **longer-term, ongoing monitoring projects,**
3. **online or app-based Community and Citizen Science projects.**

We studied one BioBlitz programme, one ongoing monitoring programme, and one online or app-based programme at each museum. Our research focused on young people aged 5–19 years as they took part in these programmes. We aimed to investigate the impact of these project types not only on how young people learn science content and skills but also on how young people take up and develop roles and identities around science and use this to take action in small or large ways in their own lives. This is based on a learning framework called Environmental Science Agency (ESA), described later in this guide.

Year 1 Apr 2017-Mar 2018	Year 2 Apr 2018-Mar 2019	Year 3 Apr 2019-Mar 2020	Year 4 Apr 2020-Mar 2021	Year 5 Apr 2021-Mar 2022
Phase 1	Phase 2	Phase 3	Phase 4	
Develop research methods and tools, and characterise learning settings and youth participation	Identify key processes and strategies to support development of ESA in existing programmes	Use Design-Based Research to implement and study changes to programmes	Data analysis and dissemination to researcher and practitioner audiences	

Our research questions:

1. **What is the nature of the learning environments and what activities do youth engage in when participating in Natural History Museum-led Community and Citizen Science?**

We wanted to understand what activities and tasks young people really do when they take part in a Community and Citizen Science project (versus what we as project designers might think or hope they do!).

2. **To what extent do youth develop the following three science learning outcomes through participation in Natural History Museum-led Community and Citizen Science programmes?**

a. An understanding of the science content and norms
b. Identifying roles for themselves in the practice of science
c. Developing a sense of agency to take action using science

We wanted to understand whether and how participation in our Community and Citizen Science programmes led to these three elements of science learning.

3. **What programme features and settings in Natural History Museum-led Community and Citizen Science foster the three science learning outcomes (a, b, and c)?**

We wanted to understand how we could better design Community and Citizen Science programmes to enhance learning outcomes for young people.

We gathered data over the course of four years, using pre-and post-participation surveys, observations, and interviews with young people and programme facilitators to investigate young people's participation and learning. We undertook qualitative and quantitative data analysis and collaborated across research teams and organisations to develop our research findings. This guide shares our key findings and recommendations for the informal science learning community.

Citizen scientists gather data at a BioBlitz in California

Sweep netting at a London BioBlitz

The programmes we studied

SHORT TERM EVENTS

BioBlitzes are wildlife surveys that bring together professional scientists, volunteer naturalists, and members of the public to create a snapshot of biodiversity within a set location over a defined period, often 24 hours (Robinson et al., 2013). Shorter events are commonly referred to as mini-BioBlitzes, and it is these shorter events that were studied within the LEARN CitSci project.

BioBlitzes combine the collection of scientific data with public engagement and are varied in form, with Baker (2014) describing them as 'part contest, part festival, part educational event, part scientific endeavor'. Scientific data collection at BioBlitzes usually takes the form of making biological records using a paper-based recording system or an app such as iNaturalist. The specific BioBlitz events studied within LEARN CitSci differed in goal, scope, and implementation. However all emphasised the importance of curiosity in, and observation of, the natural world and collection of biodiversity data, using iNaturalist at US institutions and paper forms in London.

BioBlitzes were carried out in museum grounds, urban parks, beaches, or other natural spaces close to the institutions or partner organisations. The US BioBlitzes usually included an informal whole-group introductory session explaining the goals of the event, training on using iNaturalist, and a wrap-up session with highlights on what was found. UK BioBlitzes tended to consist of drop-in activities with a welcome desk providing an introduction to participants as they arrived.

BioBlitzes in Los Angeles and London sometimes included other activities, such as handling museum specimens, live animal meet-and-greets, meeting representatives from environmental organisations, and non-scientific activities including face-painting and storytelling.

ONLINE OR APP-BASED PROGRAMMES

iNaturalist is an online Community and Citizen Science platform and scientific social network that asks participants to upload pictures or sound files that document the presence of various species and help identify these observations. After submission, they are openly accessible and can be used to inform biodiversity research or conservation land management practices. iNaturalist users can undertake a range of tasks, including (a) uploading and identifying an observation, (b) suggesting a correction to a given identification, (c) commenting on an observation or identification, and (d) discussing with others.

Zooniverse is an online crowdsourcing platform that hosts multiple research projects at any one time. Volunteers take part in Community and Citizen Science projects across a wide variety of research domains, and tasks vary according to the research need. They may include: (a) answering questions, (b) transcribing text, (c) marking regions of images, and (d) identifying the species in an image from a provided list. Once all required tasks are completed on a single image (or other piece of data), this is called a classification. The platform also offers the opportunity to chat online with project scientists and other users.

ONGOING MONITORING PROGRAMMES

Science Action Club is an out-of-school education programme. It leverages Community and Citizen Science to address science, technology, engineering, and maths (STEM) learning goals, teach discrete STEM skills, and build STEM identities among the next generation of critical thinkers and environmental stewards. The programme features environmental science units that empower after-school and summer learning programme staff to take elementary and middle school youth outdoors to investigate nature, contribute to authentic science research, and design strategies to protect the planet. There are three distinct modules; for this research project we studied Bug Safari, where youth searched for arthropods, collected specimens, and uploaded photographs to iNaturalist.

Big Seaweed Search is a partnership between NHM London and the Marine Conservation Society. It is a UK-wide Community and Citizen Science project that asks volunteers to survey a 5m wide transect of their local coastline for 14 specific seaweeds affected by sea temperature rise, ocean acidification due to increased carbon dioxide in the atmosphere, or the spread of non-native species. Monitoring seaweed abundance and distribution contributes to the understanding of global climate change and its impact on marine life. Data and photos are submitted via a website form or by post. The project is open to all, including adult groups, families, schools, and youth groups.

SuperProject is a year-long Community and Citizen Science programme. Its broad goals are: 1) to fill in biodiversity data gaps present in the Los Angeles region; 2) to contribute species occurrence records to various research projects led by Urban Nature Research Center scientists; 3) to meet the needs of the community scientists who opt into the programme. Participants include families, adults, and teachers with their students.

SuperProject participants volunteer their time to survey nature in their community – from their own yards and immediate neighbourhood to local open space and vacant lots nearby. Participants attend a 3–4 hour training before the beginning of the project. Over the course of the year, participants are invited to BioBlitzes, meet-ups, and parties where they have an opportunity to interact with museum scientists (virtually during the COVID-19 pandemic) and are sent regular emails with project updates and participants' discoveries. Observations are recorded using iNaturalist.

Guiding Learning Theories

Guiding learning theories

An understanding of relevant learning theories can help informal science learning practitioners to make evidence-based decisions about their project design and to ground their practice in the latest understanding about how people learn.

Within LEARN CitSci, the opportunity to examine youth participation in Community and Citizen Science across outdoor and online settings allowed us to study how both social and physical environments can influence learning. This ties in with the assertion within learning research that the process of learning is not abstract or de-contextualised, but co-constructed through social participation in activities (Vygotsky, 1978).

We drew on a large body of learning research but used two theoretical frameworks to guide our research: 1) Cultural-Historical Activity Theory and 2) Environmental Science Agency. They provided useful practical frameworks to understand and study participation and learning through Community and Citizen Science.

Cultural-Historical Activity Theory
Cultural-Historical Activity Theory (CHAT) (specifically the second generation of this theory) provided a framework that enabled us to identify the structures and characteristics of any given Community and Citizen Science programme, breaking it down into a series of components that each influence how someone participates in the programme and how and what they learn. The CHAT framework encouraged us to closely examine these components or characteristics, and we used them to guide our thinking about settings and features that Community and Citizen Science project developers could deliberately change or adapt to enhance the learning outcomes for participants.

This framework could be applied to any informal science learning activity and could be used to assess how each component of a given activity supports or shuts down opportunities for participation and learning.

CHAT identifies seven components within a learning setting: Subject, Objective, Tools, Outcomes, Rules, Community, and Division of Labour.

We added two additional components to this framework for our research – the Location and the Framing of the activity. These allowed us to think about the relationships between place and how the facilitators were setting youth up to engage in the Community and Citizen Science activity.

Cultural-Historical Activity Theory in brief

Cultural-Historical Activity Theory is a sociocultural theory that examines the benefits and constraints of the interconnected components of activity systems (Cole, 1988; Engeström, 2001). It starts from the premise that learning is both a social and cultural process and adopts a systems-thinking approach (that the activity system as a whole is the primary unit of analysis). The theory has evolved over time with three generations of the theory now recognised.

We suggest reading Cole (1988) and Engeström (2001) to learn more.

Environmental Science Agency
In this project, we wanted to go beyond the more traditional ways of thinking about science learning to include newer areas of research in science education. We were interested not just in how youth may gain scientific knowledge and skills, but also in whether and how they use those in meaningful ways in their own lives. This leads us to the idea of agency. Agency is the capacity of individuals to act autonomously and to make their own free choices; however, a person does not have agency as much as a person enacts agency, so it is not a static feature of a person. Importantly, an individual agent and the choices they make may be determined, limited, or enabled by social structures, including social class, religion, gender, ethnicity, ability, customs, and so on (Giddens and Sutton, 2014). Building on this, Calabrese Barton and Tan (2010) call attention to the socially transformative nature of agency at the intersection of these factors. So, when youth at an after-school programme become involved in planning the learning activities they are being offered, or when they adjust the rules of game-based learning to make them more relevant to their own lives, those young people are expressing agency.

Components within a learning setting

In this project, we used the theoretical framework of Environmental Science Agency (Ballard, Dixon and Harris, 2017), which is an adaptation of Basu and Calabrese Barton's (2009, 2010) concept of Critical Science Agency. Critical Science Agency is about using science and other powerful forms of knowledge to address issues of injustice in one's life. Environmental Science Agency (ESA) focuses specifically on environmental science, and so is about people using environmental science skills and experiences to take action on environmental and community issues they care about.

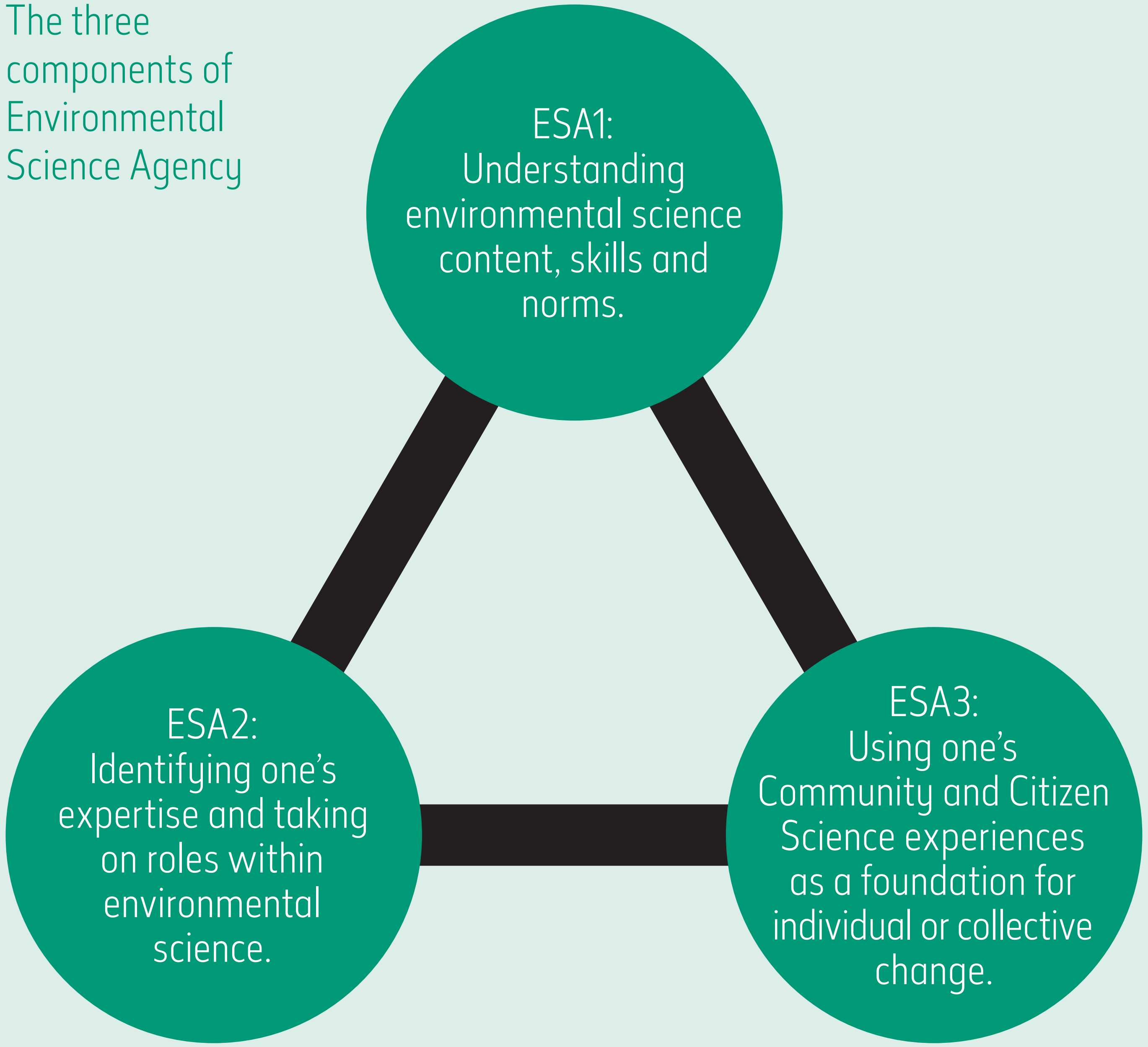
The ESA framework provided a flexible and comprehensive approach to interpreting young people's learning processes and outcomes through participation in environmental Community and Citizen Science projects. There are three components to ESA, which are intertwined, but we find that separating them out helps one to think about the individual parts as well as the whole.

The three components of ESA are not sequential or cumulative – any one or a combination of the three outcomes may be achieved and one does not rely on the other. Collectively, they comprise a well-rounded set of learning outcomes applicable to many informal science learning settings, including Community and Citizen Science.

How is the ESA framework useful to practitioners?
Breaking down the potential learning outcomes into these three components helped the natural history museums in this partnership to see what types of learning outcomes could potentially be achieved from our Community and Citizen Science programmes and consider what features of our programmes might be supporting or inhibiting these types of learning. Many Community and Citizen Science programmes have implicit or explicit goals of attitude and/or behaviour change towards more pro-environmental behaviours through participation. ESA provides a structure for project designers to consider how such outcomes could be better facilitated, not assuming that increased knowledge will lead to behaviour change, but supporting participants in this journey through developing their identities concerning science and a sense of agency for taking action.

Observing and studying the development of ESA in young people
Our team of educational researchers used observations, informal walk and talk chats as young people took part in Community and Citizen Science activities, pre- and post-participation surveys, and post-participation interviews with young people to study the development of ESA in young citizen scientists. We identified multiple science learning outcomes in young participants across the three ESA components, where young participants used their agency to develop learning or reinforce existing knowledge and skills with environmental science.

We suggest reading Ballard, Dixon and Harris (2017) and Harris and Ballard (2021) to learn more.



ESA1: Understanding the environmental science content, skills and norms.

Young people develop and/or reinforce previous existing knowledge, use environmental science concepts and terminology, understand norms shared by scientific communities, and expand their scientific skills and tools. For example, young people may understand what Community and Citizen Science is and the purpose of their data collection for scientific research.

'...[during the survey] we made sure that more than one person checked the type of seaweed. The first week, we were checking the seaweed and we were marking it down as one seaweed, then someone else was like "Hang on a second, that's the wrong type of seaweed". After that, we made sure that more than two people checked to make sure that we've got the seaweed right.'
13-year-old White female participant in Big Seaweed Search

ESA2: Identifying one's expertise and taking on roles within environmental science.

Young people develop new roles and identities with science. This may happen throughout their participation in Community and Citizen Science, e.g. identifying themselves as the one who is good at exploring and finding insects at a BioBlitz, the one who takes the photos, the one who records the data on the datasheet, the one who is good at using the microscope to identify species, etc. Youth may express increased confidence through improved performance, showing ownership of the data collection methods and identifying themselves as participants of science.

'I got better especially in the animals [project]. I was picking up variations in animals. Before doing it, my knowledge of animals out there was very limited to what was around me in Australia. By doing this, I went there's a whole world of animals out there and what they look like and how to tell them apart from each other. I can pick them up pretty quickly now.'
19-year-old White female participant in Zooniverse

ESA3: Using one's Community and Citizen Science experiences as a foundation for individual or collective change.

Youth might envision how to use scientific tools, exploration, observation, or identification skills learned or practised in Community and Citizen Science in other contexts in their lives and enact agency to use environmental science knowledge and skills in other settings.

'I am using them [learned skills] when I go on hikes – I look in small tidepools for insects.'
12-year-old White female participant in a BioBlitz

Interviewer: 'Was there anything that you would have liked to take a lead on?'

Interviewee: 'Like explore?' [...] 'I would want to investigate how you can tell which different bees, and then also I wanted to study Venus flytraps.'

Interviewer: 'Did you do any of that when I wasn't here?'

Interviewee: '[I explored] by myself. I still wanted to explore and look for different things.
11-year-old African American male participant in SuperProject.

Design-based research

Design-based research

Design-based research (DBR) is an approach or methodological framework used in the learning sciences. It involves an iterative process of introducing a design change (referred to as an intervention or embodiment) to a learning context to develop more effective learning environments, followed by studying the impacts of the embodiment on learners, the learning processes, and outcomes. The research findings are then used to inform the next iteration of intervention over multiple cycles. DBR is a collaborative and co-creative process that engages both researchers and practitioners in the process of developing effective learning environments and aligning research goals with practical goals.

The LEARN CitSci team used an approach informed by DBR, drawing on Sandoval (2014), Bakker (2018), Penuel et al. (2011), and Fishman et al. (2013) to make design changes to each of the nine study projects. Our goal was to open up more opportunities for youth learning and foster the development of ESA in each Community and Citizen Science context.

How is Design-Based Research useful to practitioners?
Historically, there has been a disconnect between theoretical insights and educational practices on the ground. DBR is an effort to connect usable knowledge with practice. A process called 'conjecture mapping' gives a stepwise structure to map how research theories or findings feed into project design, and envision the factors that may then lead to changed outcomes or impacts. With each iteration, both practitioners and researchers can step back and see whether the envisioned connection from embodiment to outcome happened and, if not, iteratively try different approaches. It breaks project design into more purposeful analytical steps, manipulating design features one at a time to identify cause and effect.

The DBR Process
- Problem analysis
- Co-defining high-level conjecture
- Conjecture mapping and co-developing embodiment ideas
- Embodiment design
- Implementation
- Data collection
- Initial reflections from practitioners
- Iterative development

We conducted a problem analysis to identify missed opportunities to enhance learning through Community and Citizen Science in each of our nine study programmes. Drawing on the evidence from the first two years of this research (ethnographic field notes, surveys, and interviews) plus practitioners' experiences and prior research, we co-developed a high-level conjecture, which formed the basis of our DBR and guided all the design changes we implemented:

'Meaningful participation in an authentic scientific research process increases youth understanding of the scientific process, identity and agency with environmental science.'

Next, we collaboratively developed ideas for potential design changes (embodiments) to our Community and Citizen Science programmes to enhance learning outcomes. We undertook a conjecture mapping exercise to help us envision how the design change might affect youth learning, map out our assumptions, and speculate as to what would be observed if the embodiment had its desired effect.

Supporting young people to use tools to explore nature can enhance their learning outcomes

The embodiments we created
The embodiments we developed were either direct (design changes the young people directly encountered) or indirect (design changes that targeted other contextual factors that could affect youth, e.g. facilitators or parents).

BioBlitz events
- Youth activity card setting out the steps to making a scientific observation.
- Facilitator card and training to help BioBlitz facilitators/staff foster and promote curiosity and critical thinking for youth with suggestions and example prompts.
- Youth science kit to encourage young people to use scientific tools to observe and record nature.

Ongoing programmes
- Framing video to frame the Big Seaweed Search's scientific purpose.
- Facilitator training video for Science Action Club leaders highlighting the importance of making nature observations using iNaturalist.
- Parent training at the start of each new SuperProject cohort to support parents to open up learning opportunities for their children.

Online or app-based programmes
- Identifications and motivational comments added to youths' iNaturalist observations.
- eNewsletters on Zooniverse highlighting research purposes and showcasing the research team.

To capture the impact of the design change, research data were collected during its implementation, including surveys and interviews with youth participants. In addition, post-implementation reflections were gathered from programme designers, facilitators, and researchers who had observed youth participating, to capture immediate feedback on its success or otherwise and consider what the next iteration might look like.

We planned two iterative cycles; however, this was not possible in all programmes due to COVID-19 restrictions. Later chapters of this guide share more detail of the embodiments, their relative successes, and our recommendations to other informal science learning practitioners.

BioBlitzes

BioBlitzes

BioBlitzes are highly popular citizen science events. What opportunities for youth learning do these events provide and how might we maximise their impact, given their one-off nature and short timeframe? Each of the three museums regularly runs BioBlitz events, and our initial observations highlighted how varied they were in scale, scope, and implementation. However, they faced similar challenges and opportunities concerning youth learning. We studied multiple BioBlitz events run by each museum, following youth as they took part in the event. This chapter sets out our key findings and recommendations for BioBlitz organisers and facilitators.

Gathering data on youth learning at BioBlitzes

We collected data from 32 BioBlitzes over three data collection periods (years):

- Broad Setting Descriptions for each event detailed the overall setting of the BioBlitz, including Cultural-Historical Activity Theory categories such as goals, framing, tools, community, and rules.
- Twenty-minute observations of youth chosen randomly from participants aged 5–19 focused on what they did, whom they interacted with, and what tools they used/were available to them.
- Pre- and post-event surveys (data collection periods 2 and 3).
- Interviews with 1–2 facilitators at each event.
- An interview with the designer of each natural history museum's BioBlitz programme.

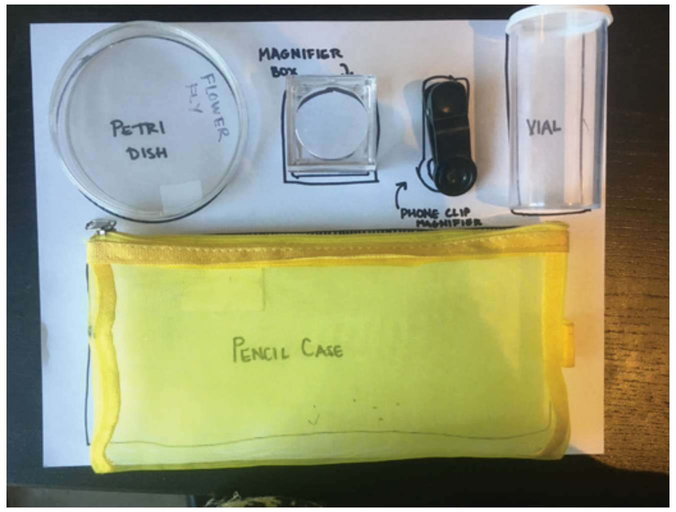
Designing for learning

Each museum implemented design changes (embodiments) to address the specific barriers to learning that each institution faced, but these were intentionally designed to be applicable in any BioBlitz setting, no matter the organiser. The effectiveness of each embodiment was then studied.

Facilitator Training Card

At the California Academy of Sciences, BioBlitz events are very community-based and we saw that interactions between youth and their parents and facilitators were one of the most important influences on youth learning, participation, and agency development. We designed a Facilitator Training Card, which was given to all facilitators (including parents) at the BioBlitz along with a short training to highlight how best to support Environmental Science Agency opportunities for the young people with whom they interact. In addition to giving concrete tips, examples, and strategies for opening up learning opportunities, the card served as a way to centre the goal of youth learning and participation, reminding facilitators of their role as educators and leaders for young people in attendance. This card can potentially be used by anyone at a BioBlitz who might take on a leadership role, including facilitators, scientists, parents, or older siblings. We recommend a short introduction

BioBlitz facilitator training cards open up learning opportunities



Example of a Community Science Kit

to the card, reviewing the points together before the BioBlitz. In addition to addressing any questions and offering further explanation, this gives time for people to intentionally think of how their role, however casual, can open up opportunities for young people to learn. If using iNaturalist, the card can be a helpful way to talk about using the app with young people together. Young people do not have to have total (or any) control over a device to participate, but it is great to involve them in as many of the steps as possible.

Community Science Kits

The Natural History Museum of Los Angeles County found that not all youth had access to scientific tools at BioBlitzes, e.g. magnifying lenses, collecting pots, or instruction on how to use them. This inhibited youth from fully observing, documenting, and recording the wildlife they found. We found that having access to tools helped youth feel like they were doing real science and supported ESA by allowing youth to take on more roles, and participate in more steps of the scientific process. Providing tools in the form of a youth Community Science Kit with an instruction guide, which they were able to take home, ensured all youth had access to scientific tools and knowledge of how to use them. Surveys revealed that all focal youth used the science kit to observe and explore at the BioBlitz and some additionally documented and identified the species found. They were excited about using the scientific tools. In some cases, we observed adults rather than youth using the kits, so providing enough for both parents and youth may be worthwhile in future.

BioBlitz Activity Card

Due to the largely drop-in nature of BioBlitzes at the Natural History Museum in London, participants were often not introduced to all the possible types of participation available across the event. In particular, there was a lack of introductory framing around Community and Citizen Science and awareness of the scientific purpose of the BioBlitz. There was a missed opportunity to support participants to take part in recording and sharing data in addition to exploring and finding species. We created a card on a lanyard, highlighting the steps involved in making and sharing a biological record. As an incentive, we included a space for participants to claim a sticker when they completed each task at the BioBlitz.

Our research data showed that participants used the activity card but generally did not relate their participation in the BioBlitz to the steps on it, instead focusing on attaining each sticker. Although BioBlitz facilitators were given information about the card in advance, not all read this and so were unaware of how best to facilitate its use. The next iteration of this embodiment will include facilitators and activity leaders introducing the card and highlighting which step(s) in creating a biological record their activity will achieve, and how it fits in the process of gathering data for research. Different formats to complement the lanyard card, such as pop-up banners at the event entrance and around the site featuring the same graphics, may also serve to reinforce how event activities relate to the steps in the scientific process and scientific purpose of the event.

What we learned

Types of participation at BioBlitzes.

We identified three participation profiles, determined by which of the five steps youth undertook (see BioBlitz Activity Card). The

The BioBlitz Activity Card set out the steps of the scientific process, highlighting the different ways that youth could take part

'Environmental Education' profile saw youth discover, observe and/or identify species but not document them in any way. The 'Natural History' profile included youth who documented their observations but didn't share them, whereas the 'Citizen Science' profile also shared their observations for scientific purposes (Lorke et al. 2021). Understanding these participation patterns can inform event goals, design and evaluation.

Missed opportunities for submitting and sharing records.
We found that observing species was the most prevalent activity that youth took part in at BioBlitzes, with exploring and searching for organisms more commonly observed in younger ages. Relatively few youth were observed making and sharing biological records, which is usually the scientific goal of a BioBlitz. If organisers are aiming for participants to gain awareness and understanding of the scientific process (Robinson et al., 2013), participation in the whole process of data collection and sharing should be desirable to enable youth to experience the full range of the science practices and methods within an authentic context (Braund Reiss, 2006). The collection and sharing of scientific data is what distinguishes Community and Citizen Science from other types of environmental education (Hecker et al., 2018). Our data suggest that programmes need to offer additional support, e.g. facilitator/parent training, iNaturalist introductions, etc. to empower young people to participate in this step of the scientific process.

Don't tell them the answer!
Identification of organisms at BioBlitzes took on a variety of forms, the most prominent being using a knowledgeable person, but identification tools such as guides and the iNaturalist app were also used. We observed two types of facilitation in BioBlitz identification – telling the young person what the organism was, and engaging in discussion and supporting the young person to determine the identification themselves. Providing the latter type of support encourages youths' participation in the data generation practices (for the identification step in particular), opening up or enhancing opportunities for ESA learning. Facilitators were also important in framing the event as a scientific activity and in teaching or supporting participants in using scientific tools; simply having the tools available was insufficient.

Train the facilitators.
We found that different facilitators at BioBlitz events had different perspectives and experiences, e.g. the Community and Citizen Science practitioner who organised it, a scientific researcher leading a specific activity, volunteers and staff members who signposted the event or supported participation, and parents/guardians. To get consistent framing and messaging, we found it useful to think about how to engage all these facilitators and support them to consistently frame the BioBlitz as a scientific survey and to support youth learning. Our embodiments give some examples of how this might be achieved.

Support transferable skills.
We found that youth participated in other activities at BioBlitzes that were not directly related to Community and Citizen Science tasks but may be important for increasing ESA, including leading and helping others and sharing science knowledge, skills, and findings. Some youth showed environmental stewardship behaviours by putting organisms back where they found them or asking others to behave in this way.

Recommendations

- Frame the BioBlitz as a scientific survey and highlight the opportunities to take part in scientific activities, to connect participants with the scientific process.
- Provide field work equipment, identification and data collection tools but also support participants in how to use them.
- Train BioBlitz staff, volunteers or other facilitators in good practice that supports and opens up learning opportunities and brief them on how to frame the event.
- Guide participants through the process of identifying organisms, rather than giving them the name only.
- Don't forget about the other learning opportunities available at BioBlitzes outside of scientific data collection, such as helping others and sharing findings.

(Right) Submitting observations of nature at a BioBlitz, using the iNaturalist app

Ongoing monitoring projects

Ongoing monitoring projects

Ongoing monitoring projects provide a markedly different participation experience to one-off short-term events, such as BioBlitzes. By participating repeatedly over a period of weeks or months, participants have more time to become familiar with a programme and the facilitators or other participants, to build relationships, and to develop their knowledge and skills over time. It also gives the programme designers multiple opportunities to engage participants in a range of tasks and introduce and reinforce different concepts. It follows that we would expect ongoing monitoring projects to provide greater scope for learning and the development of ESA.

We studied three contrasting projects – Science Action Club at California Academy of Sciences, SuperProject at the Natural History Museum of Los Angeles County, and the Big Seaweed Search at the Natural History Museum in London. Participation took place over the course of a few weeks for Big Seaweed Search, a few months for Science Action Club, and a full year for SuperProject. The contexts were also different: SuperProject participants were a mixture of families, adult-only groups, and some teachers (though we only studied youth in family groups), Big Seaweed Search involved a hybrid of a youth group and family participation, while Science Action Club took place within an after-school youth group. Despite these differences, these projects share a common goal of supporting participants to gather and submit observations of species for scientific research and biodiversity monitoring.

Gathering data on youth learning

Year 1: Observing and describing the overall activity setting, 20-minute observations of youth taking part in multiple sessions.

Year 2: Observing and describing the overall activity setting, 20-minute observations of youth taking part in multiple sessions, walk and talk interviews during observations, pre- and post-participation surveys, semi-structured interviews with youth participants.

Year 3: For Big Seaweed Search and SuperProject – pre- and post-participation surveys and interviews with selected youth participants (observations were not possible due to COVID-19 restrictions). For Science Action Club – as for year 2 (but data were only gathered from one Club due to COVID-19 restrictions).

Opportunities to enhance youth science learning
As explained in the design-based research chapter of this guide, problem analysis (i.e. identifying an opportunity for improvement) is the first step in the process of enhancing learning. Two key missed opportunities emerged:

1. **Youth not feeling connected to the scientist involved and not understanding the scientific purpose of the activity**
2. **Youth not participating in the data submission step**

Observational data showed that the ongoing monitoring programmes we studied varied significantly in the extent to which the science research was highlighted to participants, and therefore opportunities to engage young people in the scientific process were missed.

At the start of the project, youth did not consider the Big Seaweed Search as doing science:

"I didn't understand how it was science"
"...it was just counting seaweed".

The research highlighted the role of the facilitators in framing the activity as science research, communicating to the youth participants about the science, supporting them to use scientific tools in their exploration, and actively involving youth in the data submission step (passing data on to a research team or submitting it to a recognised database). We identified the data submission process as potentially important in youth science learning and the development of agency as it reinforces the wider context of the activity, creates connection to external science researchers, and is what distinguishes Community and Citizen Science from other forms of environmental education.

Recording and submitting data was a common type of participation in SuperProject but rare in other programmes. This missed opportunity to submit data was particularly observed in Science Action Club where youth regularly used tools to explore the outdoor settings, but recording and data submission was mostly carried out by a facilitator and in some cases it occurred after the session when youth were not present. Pre-existing Science Action Club facilitator training introduced the concept of Community and Citizen Science and broadly how to use the iNaturalist app, but did not sufficiently support group leaders to confidently incorporate submission of data via iNaturalist into their activities.

Observations from SuperProject highlighted the role of facilitators in opening up or shutting down learning opportunities. For example, when parents/guardians provided guidance, acknowledgement, modelled participation, or positioned youth as knowledgeable and skilful, they supported youth learning. However, when parents/guardians were observed not engaging or not providing the necessary tools (i.e. not allowing youth to use the family mobile phone or digital camera), they served to shut down youth learning opportunities.

To address these missed opportunities for learning and to intentionally design the ongoing monitoring projects to enhance youth ESA, we developed and implemented three embodiments (design interventions), one per project. These aimed to highlight the scientific purpose of the programmes, showcase the individual researchers leading each project, and support facilitators to involve young people in the data submission step.

Intervention 1: Showcasing the science

An orientation video was created for the Big Seaweed Search to make the relevance and authenticity of youth contribution to scientific research more explicit. The video framed the activity as science research, showcased lead researcher Prof. Juliet Brodie discussing the scientific goals, and showed young people taking part and sharing what interested them about the project. It highlighted the purpose of youth participation, that the protocols that participants use in the survey are authentic research methods, and demonstrated how their data contributes to a wider dataset that is used to achieve the scientific goals. This video was shown to youth participants as part of their introductory session to the Big Seaweed Search before they went to the coast to gather data.

Post-participation survey results show that youth became more aware of the global environmental challenges associated with seaweed and marine life. This also encouraged understanding that local beach seaweed surveys play a role in studying global environmental change. The video stimulated youth to visualise the authenticity of their participation in a scientific practice. Some of the young respondents exhibited an understanding of their potential contribution to seaweed research:

'[Observing and researching seaweed] is important because scientists believe that some species and habitats are being affected by climate change, and by observing and recording any changes we can find out if this is true, and how to prevent this in the future.'
10-year-old male participant in Big Seaweed Search

Some of the youth saw themselves involved in a scientific process:

'I think by researching seaweed I will help by giving more research to be studied making it a more accurate piece of research. I think this because the Big Seaweed Search wants as many people as possible to join.'
10-year-old female participant in Big Seaweed Search

The next iteration in our DBR would be to adapt the video further to build in elements of ESA 3, suggesting more explicitly how youth could use their skills and knowledge in other contexts and including case studies of youth who have already done this. We could also add more live elements to the training, such as an online chat with the lead researcher.

Intervention 2: Supporting facilitators

Both SuperProject and Science Action Club designed an embodiment to support facilitators to discuss the science, open up opportunities for ESA learning, and engage youth in submitting data. In this sense, they were indirect embodiments – something the youth would not directly encounter themselves but that would affect their experience of the programme.

In SuperProject, we implemented a 20-minute in-person training session for parents or guardians, supported by an easy-to-understand written guide. Both included an overview of how to best support youth in the programme, specific actions parents could take to support youth participation and learning and raised awareness that their actions can either open up or close down learning opportunities. The in-person training also included an overview of what ESA is, two brief case studies of former SuperProject youth participants and a review of the four basic steps for making an observation (explore, observe, photograph, share). We anticipated this would lead to an increase in positive adult facilitation of youth engaging in SuperProject activities.

After reviewing research data and practitioner feedback, a second iteration of the parent training expanded the guide and allocated more time during the in-person session to gauge parent/guardian's prior level of knowledge in education practices, encourage parents to share examples of supporting youth learning, and allow more time for discussion and questions. The next iteration will shift delivery to the start of the training session to allow for immediate practice of the skills and concepts and build in reinforcement of the concepts in the guide at in-person programmes and social events with parents and guardians.

A similar approach was taken within Science Action Club but delivered as a facilitator training video to be incorporated into their existing Bug Safari training programme for group leaders. It included guidance on how to facilitate children's participation in recording wildlife with the iNaturalist app (uploading and identifying photos of organisms), supporting them to take on the role of recorder, and highlighting their contributions to the process of authentic science research, thereby increasing the scope for them to develop roles and expertise within the project.

(Left) Participating in citizen science repeatedly over a period of time allows youth time to develop skills and take on roles

The Science Action Club leader who tested the facilitator training video said that it did help them feel more confident and comfortable using iNaturalist, and the youth in her programme made many more iNaturalist observations than in the other Science Action Club programmes we observed. CAS has already turned this Science Action Club-specific video into a more generic one for anyone who may be facilitating a group of youth using iNaturalist. The next steps will be to work with the Science Action Club staff to explore how the video might be incorporated into the national leader toolkit to expand the Community and Citizen Science content of Science Action Clubs nationally.

'Facilitator training was a reminder to not take the stage and encourage the youth to take charge.'
Science Action Club facilitator

Our research has highlighted that, despite citizen science projects having a research purpose and professional scientists being involved, this is not always visible to participants, and facilitators play a key gatekeeper role in this. There is great potential for youth to develop ESA through long-term monitoring projects with the right facilitation so that they are aware they are participating in authentic science. Repeated experiences allow for problem solving, adapting methods, and pursuing their own interests or questions.

'One of my favourite examples of seeing a young person develop Environmental Science Agency was a 12-year-old boy who took part in SuperProject and went from being interested in reptiles to recognising himself somewhat like an expert and calling himself the 'Salamander Whisperer'! We were able to see how he developed his skills to attract salamanders by figuring out small hacks such as creating humid zones covered with leaves for them, putting up signs to protect areas where he explored, or setting a bungee cord to lift a bush to be able to look for them more easily. He started using gloves to turn over rocks and logs when looking for salamanders. Through the programme, he met a museum herpetologist that helped him with his findings; he was very excited about that and saw himself as doing science and contributing to important research!'
LEARN CitSci researcher

Recommendations:

- Think intentionally about the framing of programmes and events: word choice, how activities relate to the scientific process, how data will be used or what questions the data will help answer, etc.
- Help and support facilitators in feeling comfortable with delivering key messages, modelling behaviours, talking about the research, and inquiry-based learning.
- If possible, scaffold programmes in a way that encourages consistent and longer-lasting engagement.

Online or App-Based Settings

Online or app-based settings

We studied two of the biggest online Community and Citizen Science platforms, iNaturalist and Zooniverse.

iNaturalist is an online Community and Citizen Science platform, app, and scientific social network that asks participants to upload pictures or sound files that document the presence of various species and help identify these observations. After submission, they are openly accessible and can be used to inform biodiversity research or conservation land management practices. Users are invited to complete tasks on iNaturalist, including (a) make, upload, and identify an observation, (b) suggest a correction to a given identification, (c) comment on an observation or identification, and (d) discuss with others.

Zooniverse is an online Community and Citizen Science platform. Volunteers take part in a wide range of projects, performing the following tasks: (a) question tasks, (b) free text entry tasks, (c) marking tasks, and (d) survey tasks (asking volunteers to identify the species they can see from a list). Once all required tasks are completed on a single picture (or other piece of data), this is called a classification.

iNaturalist Youth Engagement

In year 1 of the project, we examined the participation log files of 183 young volunteers on iNaturalist. They were identified during BioBlitzes organised by the Natural History Museum of Los Angeles County and the California Academy of Sciences in San Francisco. Young people were not systematic in their contributions, and the majority of them (59%) contributed for one or two days only. Most of them contributed 0 to 26 daily observations and a small number of them had an extremely high number of daily contributions. This may be explained by the fact that these participants used iNaturalist as part of a BioBlitz facilitated by museums and had no facilitation or support to carry on doing this thereafter. Also, we identified that the greater the number of active days a young volunteer had on the platform, the greater the daily contributions they made on the platform.

Looking at the patterns of participation of young people, we identified four main profiles of users as follows:

1. Lasting users were linked to iNaturalist for a long period, yet they had few active days and their participation was not systematic.
2. Systematic users were linked to iNaturalist for a long period and they had systematic visits, yet their activity was relatively low.
3. Moderate users were not linked to iNaturalist for a long period, they had relatively systematic visits and relatively low activity.
4. Visitors were active for only 1 or 2 days.

The majority of the young people we studied were either visitors or systematic users.

We compared the contributions of young volunteers to that of adult volunteers on iNaturalist and found that young people were more likely to observe molluscs, arachnids, and insects and less likely to observe plants and birds. Also, the contributions of young volunteers were less systematic than those of adults on iNaturalist and other Community and Citizen Science platforms.

Follow-up interviews with young people showed learning benefits from taking part in iNaturalist, in particular:

...developing scientific knowledge

'On iNaturalist I could upload, I could take a picture of them, upload it and people could basically tell me what it is. Like, help me find out.'

...gaining expertise or becoming better in a science-related area

'By using iNat, I could see the people in my area what they found and it's really interesting sometimes because they find stuff that you would have never thought would be where you live and it is.'

...developing a new role or taking up a new initiative

'...it feels like there's a fundamental reason why it is that amphibians cannot survive in salt water and I now wanted to know what that is so I reached out to someone I know on Twitter who did studies on amphibians. What's the issue? Why is it that amphibians cannot survive in salt water? Beyond that, I feel like iNaturalist just helps me.'

...transforming own practices

'I did some investigation on my own [...] so I went and got this photo in a photo editor and kind of did some changes to be able to see the scales clearly because the picture is not perfect. I wasn't able to see the important scales which is on the face to be able to tell the difference but eventually I went and I wrote down my reasoning for saying that this is probably guifarroi and here, the snake venom researcher from the UK said that is probably correct. That's one of the times that I did an investigation kind of by myself.'

Young people gathered and shared biodiversity data using the iNaturalist app

Enhancing learning through iNaturalist

Employing the Design-Based Research methodology, we implemented a design change to try and increase longer-term learning and engagement. Researchers systematically identified and commented on young people's iNaturalist observations. Four of the young people recruited were younger than 10 years old, 11 were 10–15 years old, and 21 were 16–19 years old. Twelve of them shared an account with their parents. For each user, recruited either through BioBlitz events or social media, our team left one identification and one motivating comment on three different observations, and this process was repeated for three weeks. Over the course of the three weeks, we tracked engagement with the observations, noting whether the young person logged on to the platform, commented on or identified the observation, or if another user commented on or identified the observation. We aimed to investigate whether experts engaging with young people's observations had an impact on their long-term participation and learning. Initial analysis has shown that the majority of participants engaged with the comments and identifications made, mainly by replying with a comment. Their comments were mostly to thank us for the response and to ask for or share further information. A few comments showed evidence suggesting that youth had learned something new from engaging with scientists. Follow-up interview analysis will shed more light on whether, and how, interacting directly with scientists could support participation and learning via iNaturalist.

Zooniverse Youth Engagement

In year 1, we examined the participation log files of 104 young people. We identified that the majority were female (67%) and between 16 and 19 years of age (95%). We then looked at their patterns of participation on the platform and identified five different profiles:

1. Systematic - volunteers in this group visited the platform at regular time intervals and were very active during their stay on Zooniverse. (5 people)
2. Moderate - volunteers' visits were at a constant rate, yet they were neither linked to the platform for a very long time nor very active during that period. (16 people)
3. Casual - volunteers visited irregularly and were not very active during the period that they were linked to the platform. (8 people)
4. Lasting - volunteers remained linked to Zooniverse the longest did not visit the platform very regularly, and had a small number of active days during the long period that they were linked to Zooniverse. (40 people)
5. Visitors - volunteers contributed to projects once or twice only, with active days during their short stay on Zooniverse. (34 people)

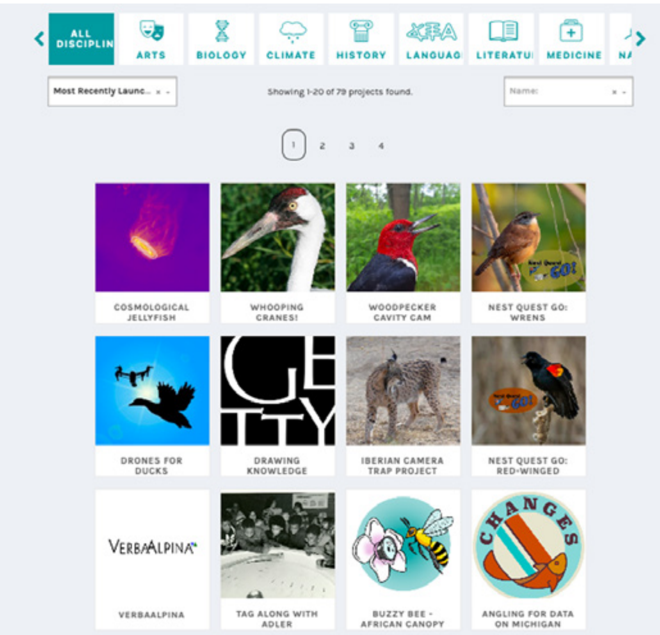
The majority of the young volunteers we examined were not regularly active on Zooniverse. Rather, they were active for short bursts of time. Over 50% of the participants contributed fewer than 200 classifications in total. There were 12% who contributed more than 1600 classifications. We found no statistically significant difference between the number of contributions from male and female volunteers.

In a follow-up study, we explored the learning outcomes of 64 young volunteers who responded to a survey about Zooniverse. Participants were mainly White, between 16 and 19 years old, with some previous science capital; for example, they reported visiting science-related content online, talking with others about science when not in school/university, and liked learning science both in and out of school. After taking part in Zooniverse, the majority of participants reported knowledge about how Community and Citizen Science works, felt confident and 'like a scientist', got better at learning or doing science, changed their way of thinking about science, and developed questions for which they wanted an answer. Young people with an interest or previous experiences in science were found to be more likely to report learning benefits from taking part in Zooniverse.

Interviews with young volunteers (n=39) gave us more insights into what young people thought about Zooniverse and how taking part in projects created certain learning benefits for them:

….enhanced understanding of science and how data are used
'To my understanding with Penguin Watch, CS is to have a lot of volunteers go over the same images and count the number of penguins in each image, and then they use that data to figure out breeding and population patterns throughout the season.'

….developing expertise and confidence in science
'I got better especially in the animals one. I was picking up variations in animals. Before doing it, my knowledge of animals out there was very limited to what was around me in Australia. By doing this, I went there's a whole world of animals out there and what they look like and how to tell them apart from each other. I can pick them up pretty quickly now.'



The Zooniverse hosts around 100 active citizen science projects covering a wide range of research disciplines.

…developing agency in terms of contributing to science in the future
'I'm excited to explore the platform more and obviously I do want to work on projects and I would like to also start one in the future because I really love how the platform gives you the chance to start a project.'

Enhancing learning within Zooniverse

To promote agency, learning, and engagement among young volunteers on Zooniverse, we implemented a design change to the newsletter format and frequency of dissemination on the popular Penguin Watch projects. The key idea was to make the science and the scientists more visible to the volunteers by sharing information about who the scientists are and how project contributions are used to inform science. Four newsletters featuring the design changes were delivered over a period of one month (a much higher cadence than normal for the average Zooniverse project). We aimed to investigate the effect of these newsletters on the frequency of participation of young volunteers on the project, as well as whether the content shared had any impact on their learning. For this purpose, we collected, and plan to analyse, the log files of young volunteers as well as data from follow-up interviews.

Recommendations

- It is important to understand that youth volunteers on Community and Citizen Science projects follow many distinct patterns of participation.
- It is important to understand who the young people are and design or make modifications to Community and Citizen Science projects in ways that will make it easy for them to take part and enable systematic engagement.
- Community and Citizen Science projects should diversify their recruitment strategies to target young people, so the learning benefits of participation are experienced more equitably.
- Making design changes to Community and Citizen Science projects has the potential to lead to increased youth engagement and learning; however, it is key that the research teams on the projects are available to help implement those changes and that they are invested in the reasons for making them.
- For hybrid programmes with in-person and online components, be sure to engage with participants in both settings to create continuity and connection between the two ways of participating.

(Right) Online and field-based citizen science settings can overlap when smartphone apps are used at outdoor events

Impacts on our Community and Citizen Science Programmes

Impacts on our Community and Citizen Science Programmes

The impact of LEARN CitSci on our programmes was noticeable throughout the project. As practitioners, we were acutely aware of our researcher colleagues attending our programmes, recording us, making observations, and gathering data. This led us to think more intentionally about programme framing, facilitation, and follow-up. Further, some of the changes we made via the embodiments we implemented through DBR will be continued in our programming – in some cases staying the same and in others being adapted to meet changing needs. From small tweaks to big changes, the impact of LEARN CitSci on our programmes will be lasting.

'This research has made me realise that even relatively small programmatic changes have the potential to make a big difference in the outcomes our projects achieve.'
Lucy Robinson, NHM London practitioner

Impacts on BioBlitz events
LEARN CitSci elucidated the importance of framing for a BioBlitz, in particular how it influenced how youth thought about the purpose of the event and their role in it. Therefore, making the direct connection to how participating in a BioBlitz is participating in science has become a key part of our introductions. This includes discussing how observing and documenting are key parts of the scientific process, how BioBlitz data are used, and when possible introducing some of the data users (such as scientists or park rangers) to help youth – and the rest of our participants – appreciate how they are contributing to the scientific understanding of the particular place we are BioBlitzing. To help participants see and try all the different roles that lead to creating a species occurrence record, NHM London and NHMLA will continue using the BioBlitz card and community science kits they created as DBR embodiments, adapting the designs to more explicitly focus on the different roles, as well as to appeal to a wider age range.

Another important source of information for BioBlitz participants is the facilitators. LEARN CitSci gave us an insight into how thoughtful facilitation could open up learning and agency in youth, both through direct interactions and also in indirect ways, such as modelling behaviours and actions. In our roles as facilitators, we are much more cognisant of purposefully exhibiting the types of behaviours we hope to see in our participants – such as walking slowly and observing carefully, and being curious and asking questions about what we are seeing. We are also more aware of not just giving answers, but helping participants learn more by talking through ideas and asking them questions to help lead them to answers. For our museums that regularly work with different groups of facilitators for BioBlitzes, we have increased appreciation for the value of training and supporting our facilitators; to help us achieve our intended outcomes, they need to feel comfortable with the specifics of our research and the key messages or practices we want them to emphasise. To help with this, CAS and NHMLA will continue to use the facilitator card and facilitator training they developed as part of the DBR process. Acknowledging the important role that parents and guardians also play in the experience of a young person at a BioBlitz, NHMLA is adapting the SuperProject parent/guardian guide for use at BioBlitz events, and CAS plans to make a version of their facilitator card specifically for parents and guardians.

We are re-framing how BioBlitzes are introduced, to enhance learning outcomes

Facilitators play a key role in supporting youth learning

Impacts on ongoing monitoring programmes
In our ongoing programmes, along with highlighting the importance of framing and facilitation as in our BioBlitzes, LEARN CitSci has clearly shown the benefits of repeat participation and how learning and agency can be scaffolded through multiple interactions with the same youth. This has led us to think about how to encourage more consistent and longer-lasting engagement. NHM London is developing a more structured way of taking part in Big Seaweed Search, with associated training and mentoring that encourages participants to take part multiple times as a longer-term commitment (e.g. over a year or multiple years) rather than participating just a couple of times. Additionally, communications are connecting Big Seaweed Search to wider discussions about marine environmental health to improve learning outcomes and broader scientific relevance. Some of our ongoing programmes, such as Science Action Club and Big Seaweed Search, rely on online training to reach more participants, yet in-person training leads to higher quality data. Therefore, we are looking at ways to combine the best elements of each to create enhanced training offerings, incorporating lessons learned from LEARN CitSci.

Impacts on online or app-based programmes
For Zooniverse and iNaturalist, our two online programmes, LEARN CitSci represented the first significant study of young volunteers on each of the platforms, and lessons learned will be incorporated, albeit in different ways. The research provided the Zooniverse team with new and valuable insights into the patterns of participation and motivations of young volunteers taking part in Zooniverse Community and Citizen Science projects. LEARN CitSci uncovered information about what changes could be made to better encourage agency and learning in Zooniverse projects. These findings were used to design a newsletter template intended to promote ESA, learning, and engagement, which Zooniverse plans to implement on a wider scale across all projects in the future. For iNaturalist, the DBR embodiment of the NHM practitioners providing identifications, comments, and questions on observations made by youth encouraged more activity and regular engagement from the young people, highlighting the importance of these types of interactions. CAS and NHMLA practitioners, who use iNaturalist in all their Community and Citizen Science projects, not only plan to continue this practice, but believe it can be especially impactful for anyone new to iNaturalist: having responses on your observations is motivating, helps you feel like you are part of the community, and will hopefully encourage new participants to continue to document biodiversity after the BioBlitz or project for which they first used iNaturalist.

Beyond our Community and Citizen Science projects included in the LEARN CitSci programme, what we learned through this research has impacted our work in other ways. For example, CAS has used the LEARN CitSci transcripts of BioBlitz introductions and wrap-ups in their anti-racism work, going through that language and changing it to be more inclusive and welcoming. NHM London has used the components of ESA to structure evaluation for other projects, looking for outcomes of participants developing knowledge and skills in the scientific subject area, understanding their role in the research, and developing a sense of agency to take action on environmental issues they care about. Overall, LEARN CitSci has given us a strong foundation for how we can better design projects and activities to help people develop their own role in biodiversity science and their sense of agency so that they can advocate for nature and take action in their own lives.

Researcher-practitioner partnerships

Researcher-practitioner partnerships

The Science Learning + funding scheme that supported this research specifically sought to develop research-practice partnerships in informal science learning research. But how do such collaborations work in practice? What are the benefits, risks, challenges, and successes of this approach?

LEARN CitSci leads at each organisation were either educational researchers or Community and Citizen Science practitioners (mostly with science career backgrounds). We employed a range of strategies to support research-practice partnerships, reflecting and adapting throughout the project, and we share a few of these below.

Embedded researchers
In the UK, one of the three project postdoctoral researchers in youth science learning was employed at NHM London, so that the researcher was embedded and immersed in the practical realities of running a Community and Citizen Science programme. We recognise that this was an unusual working environment for an educational researcher, and they faced the challenge of not being embedded in a traditional research group within academia. We also created the role of project coordination officer (PCO) at each museum, a hybrid role of practitioner and researcher, with staff coming from informal science learning backgrounds. Within this project, they were trained in learning theories, qualitative data collection methodologies, and data analysis. Their role encompassed both practitioner elements of developing new resources for citizen scientists and developing and running the Community and Citizen Science programmes at each museum, but also undertaking much of the data collection for this research, observing young people as they participated in Community and Citizen Science , distributing surveys, and conducting interviews with youth. This hybrid role created multiple competing demands on their time, requiring tough prioritisation of tasks and careful liaison between project staff to agree on their work plans and manage and support them on a day-to-day basis. But their understanding of youth participation in informal science learning activities and their close working alongside programme leaders resulted in the research being grounded in the realities of Community and Citizen Science programming. It also served to build capacity for learning research within the museum sector.


Educational researchers closely examined youth participation, to identify how setting features influence learning outcomes

Training and knowledge transfer
We invested in training staff across the partnership, and this brought huge value to the team. Formal sharing of research methods through presentations and workshops in whole team meetings complemented the ongoing informal knowledge exchange. Researchers presented theories or data to the team to articulate early findings and received feedback from the practitioners, discussing together how the data might be interpreted. This encouraged all staff to constantly consider the relevance, accessibility, and usefulness of the research.

'Even though we all started on the same page and most of us wrote the proposal together, we realised that we needed some structures to keep the exchange of ideas going, instead of always getting bogged down in the logistics of the project.'
LEARN CitSci Researcher

Communication and co-creation
Deep collaboration and communication were at the heart of this project, from proposal writing to data analysis and dissemination. Near-constant communication between researchers and practitioners ensured the research was truly reflective of the real-life experiences of Community and Citizen Science programme teams. Practitioners were deeply involved in the creation and implementation of the research instruments, making them easier to implement in practice, and worked closely with researchers to translate the research findings into formats easily accessible to practitioner audiences.

'I really appreciate the high levels of collaboration in this project – having a researcher 'parachute in' for a week or two to gather data then disappear for six months just wouldn't work for us.'
LEARN CitSci Practitioner

DBR forces researchers and practitioners to co-define terms and co-identify what is meaningful to the field. Developing a common language around all aspects of this research was necessary for success.

The challenges of this deep level of collaboration primarily centred on the time commitment required to work together in this way. There was a high volume of meetings and a balance had to be struck between the benefits of having multiple practitioners feed into the development of a research instrument and the resulting slower pace of development and sign off. Instant messengers and clear commenting and signing off procedures helped to manage this.

'I had initially thought the practitioners would just give us access to the data or participants. Now I realise they can provide deeper insights into the projects, help overcome practical/logistical issues, and can add insights and much deeper layers of interpretation of the data due to their deep understanding of the projects and tools.'
LEARN CitSci Researcher

Research-practice divide and equity
Intensive collaborative research at all stages takes more time and work than token collaboration. The project's structure, led equally by one researcher and one practitioner, and our investment in research staff based at practitioner institutions helped us to work towards, but not always achieve, an equal balance across the project. It is very rare in educational research and unique within the Science Learning + scheme for a research funder to accept a practitioner as principal investigator, and we are grateful to our funders for embracing this.

Recommendations
- Team onboarding and intentional group formation need to be planned and implemented. Create space for the team to co-create expectations around the project and agree on the best ways to communicate and work through conflict and on the overall approach to leadership.
- Allocation of budget must reflect the authentic collaboration, workload, and expectations of each partner.
- Continued communication and clarification about expectations, goals, needs, and interests is crucial to ensure research is realistic and applicable and practice is reflective and evidence-based.
- Allocate time to communication and collaboration – the benefits of the partnership far outweigh the costs, but it needs resourcing.
- Discuss and agree on a fair approach to authorship of project outputs to reflect the diverse roles and expertise that lead to successful research.

Collaboration with community-based organisations

Collaboration with community-based organisations

One aspect of the LEARN CitSci project was designed to work alongside community-based organisations (CBOs) local to each Natural History Museum. Partnerships with CBOs are integral to each of the museums' Community and Citizen Science programmes, and this project sought to build upon this work to further develop accessible and relevant Community and Citizen Science programmes for their younger audiences.

Our cross-institution goal was to build partnerships that were mutually beneficial, meaningful, and lasting. Key to this process was to recognise the cost to CBO partners (in terms of both resources and time) of collaborating with us, which we achieved by means of an unrestricted mini-grant to each CBO partner. We also co-developed a collaboration agreement, setting out each organisation's goals for the partnership and how we wanted to work together.

Museum partnerships and goals

Natural History Museum London

The Natural History Museum in London developed partnerships with three CBOs. Girlguiding and the Scout Association are UK-wide networks of local, volunteer-led youth groups that aim to inspire and empower young people. We collaborated with the group leaders and the Marine Conservation Society to deliver a programme of training meetings and Community and Citizen Science surveys to connect youth with nature and enhance the Guides' and Scouts' STEM provision. Practical challenges, such as facilitators' and participants' availability for meeting and carrying out the survey and collection of parental consent were overcome through flexibility and regular communication with the group leaders. This resulted in partnerships that we continue to nurture, the production of resources for the Big Seaweed Search, which feature Guides and Scouts from the LEARN CitSci programme, and collaborating on a local natural history festival. EPIC-CIC was the youth service provider for the London borough local to NHM London, inspiring youth from low socioeconomic and BAME backgrounds to achieve their potential and make a positive difference to their community. To address their desire for STEM training and professional development opportunities for their staff, our mini-grant provision supported eight playworkers to attend two training workshops, delivered by NHM London at EPIC-CIC's office. These sessions introduced the concept of BioBlitz events, discussed learning opportunities through Community and Citizen Science, and introduced commonly used Community and Citizen Science tools (e.g. identification resources and apps).

Natural History Museum of Los Angeles County

NHMLA partnered with Community Nature Connection, an organisation working 'to increase access to the outdoors for communities impacted by racial, socio-economic, and disability injustices by eliminating existing barriers through advocacy, community-centred programming, and workforce development'. During the project, NHMLA staff worked with Community Nature Connection to co-create programming for their Naturalist Explorers (NE) youth. NE programme participants are predominantly People of Colour, so the co-created programme intentionally included scientists and educators of colour to ensure representation of museum/science professionals who looked like the participants.

Over the course of almost four years, the relationship has developed and deepened. Lessons learned have been applied to work with other partners and will be used in future partnerships. One unexpected outcome was the creation of an equitable partnership framework. After the social justice uprisings in summer 2020, NHMLA suspended their regular programming to reflect deeply on their work and how it could be explicitly anti-racist (see the next chapter). The document has been shared with Community Nature Connection staff, and with another of NHMLA's long-term partners, LA Nature For All. Both organisations gave their feedback and, through the process of sharing, worked to deepen our respective relationships. We intend to continue to partner with these organisations and look forward to power sharing, being accountable, working through any conflict that arises, and deepening our respective relationships.

Partnering with youth groups ensures projects are designed to meet their needs

California Academy of Sciences

The California Academy of Sciences partnered with Literacy for Environmental Justice (LEJ) for one BioBlitz, an organisation that 'promotes ecological health, environmental stewardship, and community development in Southeast San Francisco by creating urban greening, eco-literacy, community stewardship, and workforce development opportunities that directly engage and support local residents in securing a healthier future'. Six months before the BioBlitz, CAS and LEJ met to discuss each organisation's goals and scope for a BioBlitz event, how we could potentially work together to mutual benefit, and lay out how a BioBlitz could work in partnership. During this meeting, LEJ expressed their primary goals: decreasing barriers, youth engagement, community representation, and increasing awareness of habitat and connection to nature. They also mentioned that the data the event would generate around the ecosystem services based on previous restoration work would be useful for funding.

Neither this research nor any of our Community and Citizen Science programmes, would have been possible without collaborating with our partners. It is integral to this work, and we are always continuing to learn how to be good partners.

Recommendations

- Be realistic and intentional at the outset about what is feasible to deliver, given the time, money, and resources available to you. It takes time to create strong, meaningful partnerships and this must be factored into staff workloads. We found it took a minimum of six months to truly begin working with our partners.
- Have conversations early about goals and expectations for the partnership. What can each partner bring to the table? We found this especially important because all of our natural history museums are large, power-holding institutions. We aimed to come to conversations with our CBOs with the awareness of the power we held, with the intention to compensate our partners with more than just the name of our institution. We held meetings at partner sites/offices to address the power balance.
- It takes time and resources to collaborate effectively – we recommend budgeting to financially compensate CBOs for this. However, actually transferring money to the CBOs involved lots of red tape and was very slow and unpredictable – this was difficult for our CBOs.

Our response to COVID-19 and social justice movements

COVID-19 and social justice movements

In March 2020, all three natural history museums in the LEARN CitSci partnership were closed to the public due to the COVID-19 pandemic. As our museums sit in three different world cities, we were all in various states of quarantine, with uncertain futures ahead of us. All non-essential staff began working from home, in-person programming was cancelled, and our museums began creating virtual modes of engagement for our audiences.

As an international collaboration, the LEARN CitSci team has always connected virtually, and as such was already set up to meet, collaborate, and problem solve remotely. Strategies we already employed from the inception of the project eased our transition to pandemic virtual work, including:

- Shared project Google folder: document-sharing space holding all collaborative working documents.
- Virtual meetings: monthly, weekly, and ad hoc meetings held via Zoom or Google Hangouts.
- Asynchronous meetings: utilising a Google document where all staff can work through the posted agenda at their own pace over a two-week window. This allowed us to share updates, get feedback, and move the project forward without having to find a time to meet virtually.
- Slack instant messenger: the various channels in our Slack allowed us to communicate and share documents easily, all in one place.

COVID-19 impacts

The cancellation of all museum in-person events meant we could no longer collect observational data at many of the programmes we had planned for spring and summer 2020; however, in some cases we could collect data via online interviews with youth participants.

BioBlitzes were cancelled at all three museums, although NHMLA had already held both the BioBlitz events we were studying in year 3. CAS staff adapted the format and delivered two virtual BioBlitzes in summer 2020. Participants joined the Zoom programme from their respective homes or outdoor locations. Staff adapted their introductions for the online setting, and then encouraged participants to go out and survey their backyards, local parks, and neighbourhoods. Although not as engaging as an in-person event, they were still able to gather hundreds of observations on the iNaturalist platform. NHM London also trialled a virtual BioBlitz focused on plants as part of a wider programme of virtual activities for families, and the City Nature Challenge reoriented to an online-only format. Virtual BioBlitzes achieved mixed results, and further innovation is required to successfully deliver such events online.

Two of our ongoing monitoring study programmes were adapted to accommodate lockdowns and social distancing measures, using online formats for training and to conduct our research interviews with youth participants.

Big Seaweed Search training was shifted from a coastal location to online formats, involving an online introduction and training session with a youth group. Young people then visited the coast independently with their families to conduct the survey. We then met up again online to discuss their findings. While not as engaging as meeting in person, and teaching seaweed identification virtually was challenging, it could provide a long-term solution that strikes a good balance between staff time commitment and the number of people we can reach.

Natural History Museum London closure in 2020

The COVID-19 pandemic significantly impacted our Community and Citizen Science Programmes

To continue supporting SuperProject participants, NHMLA staff created office hour events to model and reinforce the method for making an iNaturalist observation. We moved our mid- and end-of-year project parties to Zoom, incorporating many of the previous elements, including virtual behind-the-scenes collections tours and presentation of SuperProject data. We also incorporated new modes of engagement through games and sharing participant-submitted videos/stories.

Anti-racist Community and Citizen Science

Summer 2020 saw a global social justice uprising in light of the murders of Breonna Taylor, George Floyd, Amaud Arbery, and countless others before them. Communities took to the streets in protest of the injustice and racism faced by black communities in the United States and across the globe. Our team felt we had to embark upon a course of action to tackle racism, particularly anti-black racism, in our field of study. To centre those most affected by racism, the Black, Indigenous, and People of Colour (BIPOC) members of the team were consulted by co-lead Lila Higgins about the course of action we should take. We worked through a multi-step process with the ultimate goal of implementing anti-racist actions within LEARN CitSci and future projects. Our steps included:

- Foundational readings on topics related to anti-racism, oppression and white supremacist culture
- Meeting to discuss the foundational readings
- Mapping oppressions in our project
- Theming oppressions and brainstorming antidotes
- Formation of ad hoc committees to create implementation plans for antidotes
- Intentional focus on staff well-being

The antidotes we devised included enhancing our existing group norms and values, adapting team meeting formats and agendas, a meeting planning and chair guide, collated resources about group dynamics and leadership development, and a plan for how to better work with our community-based organisation partners. All these resources were then collated into a lessons learned and recommendations document for our team.

Meet the team

Meet the team

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Project team visiting the Natural History Museum of Los Angeles County in 2019

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