MICS

Measuring Impact of Citizen Science

Developing metrics and instruments to evaluate citizen science impacts on the environment and society

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Acronyms

CBPR	Community-Based Participatory Research
CER	Community-Engaged Research
CO	Citizen Observatories
CS	Citizen Science
DITOS	Doing It Together Science
EC	European Commission
GT2.0	Ground Truth 2.0
IA	Impact Assessment
IT	Information Technology
MoRRI	Monitoring the Evolution and Benefits of Responsible Research and Innovation
MoS	Measures of Success
NGO	Non-Governmental Organisation
RIA	Research and Innovation Action
RRI	Responsible Research and Innovation
SDGs	Sustainable Development Goals
SMART	Specific, Measurable, Achievable, Realistic, Time-dependent
STEM	Science Technology Engineering Maths
ToC	Theory of Change
UK	United Kingdom
UN	United Nations
UNSTATS	United Nations Statistics Division
WP	Work Package

Executive Summary

The MICS project is tasked with setting up and implementing an Impact Assessment framework for citizen science projects that serves to capture impacts in five distinct domains: society, science and technology, environment, economy and governance. This report is a deliverable of Work Package 2 (WP2) – 'Methods for measuring citizen-science impact' which provides the conceptual insights for the development of MICS approaches and tools to assess citizen-science impacts. The purpose of this report is to present the draft MICS conceptual framework which constitutes the overarching structure within which novel and appropriate impact assessment methods will be provided for citizen science projects and which will inform the MICS online platform.

This report presents the draft version of the MICS conceptual framework [the final version will be submitted by December 2021]. The overall aim of the MICS conceptual framework is to synthesise existing methods and indicators in a coherent structure and to indicate gaps where indicators are still needed. The framework has been constructed based on the results from a systematic review of the citizen science literature on impact assessment methodologies, frameworks or approaches and the insights generated from the general impact literature which had been captured in six guiding principles (reported in MICS D2.2, Wehn et al., 2020a). These results were combined and pre-organised within a holistic intervention logic and using the five MICS impact domains (society, science & technology, economy, environment, governance) (reported in MICS D2.3, Wehn et al., 2020b).

Given the gap identified in the citizen science literature regarding indicators and approaches for capturing environmental attitudes, knowledge and behaviour, this report presents an analysis of the state of the art in the assessment of environmental attitudes, knowledge and behaviour beyond citizen science. This is built on a systematic review of relevant academic literature in these fields. The results show that while there is a range of indicators and approaches available to measure environmental attitudes, behaviour and knowledge, there is no single agreed best practice. Salient identified approaches were included in the construction of the MICS conceptual framework.

For the further construction of the framework, the details of selected indicators from the review were entered in the MICS conceptual framework in a comprehensive Excel according to a tailored MICS indicator characteristics protocol. A key step in the completion of the framework was the careful grouping of relevant indicators per domain as well as an assessment of the feasibility of their implementation.

To test the application of the MICS conceptual framework by citizen science projects, it was applied in the MICS case studies to assess the impacts of their citizen science activities, by identifying and monitoring pathways of change using the framework. The guidance provided to apply the framework in each case study was developed and provided by WP2. It was implemented in all case studies of the project in WP4, in collaboration with WP2, case study leads and members of the MICS team. The illustration of the guidance is included in this report, while the detailed elaboration with the results of each case study is provided in deliverable D4.5 by WP4.

The inputs drawn upon for constructing the MICS conceptual framework stem from diverse scientific fields and epistemological approaches, incorporating distinct perspectives and framings not only of impact assessment but also citizen science. These go hand in hand with not only diverse but also often very comprehensive data collection methods. The feasibility of these data collection methods and the implications for data management require continued attention throughout the remainder of the project. Similarly, the curation of the MICS conceptual framework during and after the project life time will need careful consideration.

1 Introduction

1.1 Background on MICS

The MICS project develops approaches and tools to assess citizen-science impacts. These approaches and tools can help to plan and implement projects in ways that lead to more robust results.

The MICS project specifically aims to:

- provide comprehensive, participatory and inclusive metrics and instruments to evaluate citizen science impacts;
- implement an impact-assessment knowledge-base through toolboxes for methods application, information visualisation, and delivery to decision makers, citizens and researchers;
- improve the effectiveness of nature-based solutions through test-site development and citizen-science tool validation;
- generate new approaches that strengthen the role of citizen science in supporting research and development;
- foster a citizen-science approach to increase the extent to which scientific evidence is taken up by policy makers through recommendations and guidelines.

The result is an integrated platform where these metrics and instruments are available for use by anyone involved in a citizen-science project wanting to understand its impact, whether at the planning stage or several years after the project's conclusion. The MICS project adopts and adapts the best practice generated by the Ground Truth 2.0 project in the co-creation of hands-on citizen science validated in four case-study sites across Europe, resulting in a comprehensive conceptual framework and clear recommendations for those involved in citizen-science projects. The four sites (in the UK, Italy, Hungary and Romania) explore the co-creation of citizen science in regions with differing needs, contexts, and approaches to environment management (for example, river restoration and nature-based solutions), and with various levels of citizen-science application. For example, in Western Europe, river restoration is increasingly carried out within an ecosystem-based management framework at river or catchment scale; in Southern Europe, river restoration tends to be issue-specific with some ecosystem relevance; in Central and Eastern Europe, river restoration is about ecosystem protection and related to existing infrastructure.

1.2 Purpose

The MICS project is tasked with setting up and implementing an Impact Assessment framework for citizen science projects that serves to capture impacts in five distinct domains: society, science and technology, environment, economy and governance. This report is a deliverable of Work Package 2 (WP2) – 'Methods for measuring citizen-science impact' which provides the conceptual insights for the development of MICS approaches and tools to assess citizen-science impacts. The purpose of this report is to present the draft MICS comprehensive conceptual framework which constitutes the overarching structure within which novel and appropriate impact assessment methods will be provided for citizen science projects and which will be implemented via the MICS online platform.

1.3 Structure of the report

This report is organised as follows. Following this introductory chapter, section 2 recaps on key terms as well as the approach for finalising the MICS conceptual framework. Section 3 presents the results of a systematic review of approaches for assessing environmental attitudes, knowledge and behaviour. Section 4 presents the draft MICS conceptual framework at three different levels of abstraction: i) the overarching impact domains; ii) the intervention logic; and iii) the indicators and methods for collecting evidence for them. Section 5 describes the application of the MICS conceptual framework in the MICS case studies. Section 6 concludes with an indication of which MICS Work Packages and tasks will capitalise on the results of this report.

2 Background and approach

2.1 Definition of key terms

This section presents relevant key terms and terminology as background information for this report on the MICS conceptual framework. Specifically, we present explanations of the elements of an intervention, the types of results in results-chain assessment approaches, the additional aspects that differentiate the Theory of Change from the (linear) intervention logic and key elements of a monitoring and assessment framework.

Box 1: Key terms and terminology

Elements of an Intervention

Objectives define and delineate the purpose and goals of a project, program or policy. Ideally, they are formulated to be SMART (Specific, Measurable, Achievable, Realistic, Time-dependent) in relation to the concept.

Concept articulates what action needs to be taken and how in response to a challenge or problem that needs solving.

Inputs are resources such as people, raw materials, energy, information (including the concept), or finance that are put into a system such as a project, program or policy to obtain a desired output.

Activities are the actions undertaken by the intervention; tasks undertaken to transform inputs into outputs. Activities are usually based on strategies.

Outputs (see definition in 'types of results')

Types of results in results-chain assessment approaches

Outputs are what is directly produced or supplied by an intervention, they often relate to the expected deliverables of the intervention and consist of tangible products or services produced as a result of the activities (and can be subject to external factors).

Outcomes capture the immediate changes in a situation, including behavioural changes that result from the intervention outputs (including intended and unintended, positive and negative changes). They generally have a clear link with the intervention, but are influenced by external factors as well.

Specific outcomes are emerging, observable.

Wider outcomes consist of the social, institutional, economic and environmental changes triggered by and attributable to (use of) the outputs and are typically more difficult to observe and/or attribute.

Impacts broadly define the (widespread) changes over a longer period of time that result from an accumulation of outcomes and affect the wider economy and society beyond those directly affected by the intervention. They are strongly influenced by external factors.

Elements of a Theory of Change

Impact domain or domains of change refers to a specific (sub) system, sector or thematic area of envisaged change(s) of an intervention.

Strategies are successful approaches which a review of the state-of-the-art has identified that helped similar communities or organisations to achieve the kinds of results the project, programme or policy is attempting to elicit.

Assumptions are statements about accepted cause and effect relationships, or estimates of a fact deducted or from the known existence of other fact(s). They provide a basis for the generation of concepts, strategies, and actions by enabling the creation of "what if" scenarios to simulate possible situations and explain how and why the strategy will work. Assumptions can be misleading when accepted as reality without examination; the Theory of Change approach ensures assumptions are transparent and accessible to validation.

Influential factors or external factors are outside influences that can impact the ability of a project or investment to achieve its strategic goals and objectives. These external factors might include competition; social, legal and technological changes, and the economic and political environment.

Elements of a monitoring and assessment framework

Monitoring: The supervision of activities in progress to ensure they are on-course and on-schedule in meeting the objectives and performance targets.

Assessment: The process of determining, judging or deciding the amount, value, quality, or importance of a something (e.g. a person or a situation); as well as the resulting judgment.

Evaluation: Rigorous analysis of completed or ongoing activities that determine or support (management) accountability, effectiveness, and efficiency (i.e. an assessment with a judgment based on organization-internal criteria). Evaluation of completed activities is called ex-post evaluation, post-hoc evaluation, or summative evaluation. Evaluation of current or on-going activities is called in-term evaluation.

Impact assessment is the study of the effects of a new project or intervention (i.e. an assessment with a judgment based on organization-external factors). Impact assessments can be conducted ***ex ante*** as a study of possible negative consequences (e.g. environmental impact assessment), or ***ex post*** to determine the summary benefits and consequences of a policy or project with dispersed effects on larger populations or geographical areas.

Validation is the assessment of an action, decision, concept, plan, or transaction to establish that it is correct, complete, being implemented (and/or recorded) as intended, and/or delivering the intended outcome (i.e. an assessment including a binary judgment such as correct/incorrect). Preliminary validation based of ongoing activities can be used as part of adaptive management to inform adjustments of assumptions and derivative actions

Baseline: Clearly defined starting point from where implementation begins, improvement is judged, or a comparison is made. A baseline study is an analysis of current situation to identify the starting points for a program or project, providing an initial collection of data which serves as a basis for comparison with the subsequently acquired data.

Formative Evaluation provides information about an intervention or project during the design and development stage (see also <u>monitoring</u>) in order to make changes that improve the final design or implementation.

Summative Evaluation is a form of evaluation assesses outcomes or impacts of a “settled” project. Summative evaluation provides information about the impact of an intervention or project; what is assessed should be tied to project goals and objectives, however there should be an effort to document unintended outcomes as well.

Indicator is a (set of) criterion(s) that help determine what data needs to be collected to assist in assessing progress of a program and where it is on track to achieving its goals and objectives

Process indicators serve to monitor the implementation of an intervention, project or programme in terms of reaching intended targets and quality as well as activities.

Outcome and impact indicator serve to monitor progress of an intervention, project or programme in terms of achieving its objectives and envisaged changes (e.g. in knowledge, attitudes, behaviour) in the short term (outcomes) and long term (impacts).

Sustainable Development Goals Tiers of indicators

Tier 1: Indicator is conceptually clear, has an internationally established methodology and standards are available, and data are regularly produced by countries for at least 50 per cent of countries and of the population in every region where the indicator is relevant.

Tier 2: Indicator is conceptually clear, has an internationally established methodology and standards are available, but data are not regularly produced by countries.

Tier 3: No internationally established methodology or standards are yet available for the indicator, but methodology/standards are being (or will be) developed or tested. *(As of the 51st session of the UN Statistical Commission, the global indicator framework does not contain any Tier III indicators)* (UNSTATS, 2018*)*

Participatory evaluation involves the stakeholders of an intervention, project or programme in the evaluation process at any stage of the evaluation process (evaluation design, data collection, analysis, reporting) and may involve quantitative and qualitative data. The type and level of stakeholder involvement will necessarily vary depending on the level of impact evaluation (e.g. local impacts vs. policy changes). (Gujit, 2014)

Source: based on EC, 2015; Morra Imas and Rist, 2009; Van Es et al., 2015; Wehn et al., 2017

2.2 Approach

The overall aim of the MICS conceptual framework is to synthesise existing methods and indicators in a coherent structure and to indicate gaps where indicators are still needed. The framework has been constructed based on the results from a systematic review of the citizen science literature on impact assessment methodologies, frameworks or approaches and the insights generated from the general impact literature which had been captured in six guiding principles (reported in MICS D2.2, Wehn et al., 2020a). These results were combined and pre-organised within a holistic intervention logic and using the five MICS impact domains (society, science & technology, economy, environment, governance) (reported in MICS D2.3, Wehn et al., 2020b).

For this deliverable, the details of indicators identified in MICS deliverable D2.3 were entered in an Excel according to the tailored MICS indicator characteristics protocol (also presented in D2.3). The structure of the Excel is as follows (see Table 1). The content of the Excel is available in Annexes 6-10.

Table 1 Excel structure of MICS conceptual framework

Tab	Description
Start here	Table with description of the indicator items that are used in the five MICS impact domains
Tab 1 - Impact Domains	Overivew of the definitions of the five MICS impact domains
Tab 2 Intervention logic	Summary of the MICS intervention logic (illustration)
Tab 3 - Index	Summary of themes and indicator titles per domain
Tab 4 -Society	List of relevant indicators for the society domain (with details according to the MICS indicator characteristics protocol)
Tab 5 - Science and Technology	List of relevant indicators for the science & technology domain
Tab 6 - Economy	List of relevant indicators for the economy domain
Tab 7 - Environment	List of relevant indicators for the environment domain
Tab 8 - Governance	List of relevant indicators for the governance domain

The domain tabs were completed with the full information for each indicator identified during the literature review. A key step in the completion of the framework was the careful grouping of relevant indicators per domain and an assessment of the feasibility of their implementation. Specifically, thematically-related or even overlapping indicators were clustered (i.e. their columns moved next to each other in the Excel and marked with a common colour code at the indicator title field) for easy identification. The assessment of the feasibility of the implementation of each indicator was done based by considering the proposed data collection methods, sources and maturity of data collection items as well as indicator building specification. The feasibility of indicator was categorised as either resource demanding, moderately resource demanding, slightly resource demanding or minimal resources required. Indicators that missed information in the fields used to assess the feasibility were categorised as ‘insufficient information to judge’.

The development of the framework resulted in distinctly different inputs per MICS impact domain, with the largest number of relevant publications in the society impact domain and the lowest in the economy domain. It therefore remains necessary to identify missing themes and indicators, drawing on other relevant research areas. This was the case, for example, for soundly measuring environmental knowledge, attitudes and behaviour which has been addressed by drawing on the state-of-the-art in environmental psychology (see systematic literature review presented in section 3).

Moreover, for this deliverable, detailed guidance was developed and provided to the MICS case studies in WP4 to allow them to apply the MICS draft conceptual framework. This process is reported in section 4.

3 Assessing environmental attitudes, knowledge and behaviour

3.1 Methods

The analysis of the state of the art in assessment of environmental attitudes, knowledge and behaviour described in this report is built on a systematic review of relevant academic literature in these fields. As these are three distinct, yet related concepts, distinct searches were conducted. However, due to the degree of overlap and similarity between the concepts, some of the literature identified during this search is relevant for all three.

The process of selecting relevant literature for this systematic review was based on the steps suggested by Moher et al. (2009) and as applied by MICS in D2.3. The purpose of the systematic literature searches was to identify publications that propose or discuss frameworks or scales for assessing environmental knowledge, attitudes (environmental concern) and behaviour.

The search for literature was done on Web of Science and Wileys Online Library (following an initial search on Google Scholar), between February - April 2021. Keywords were compiled that referred to the concepts of; (1) environmental attitude (2) environmental behaviour and (2) (environmental) knowledge. A set of keywords that refer to the concept of environmental attitudes, environmental behaviour and environmental knowledge, or closely related fields were identified (see Tables 2 and 3). Similarly, a set of keywords was identified for the second aspect of the search, which relates to measurement or assessment of these concepts. The Boolean operators “AND” and “OR” were used to combine the search terms and the asterisk wildcard (*) was used to include different variations of each term. To specify the exact phrases that should be contained within the search, quotation marks (“”) were used for each of the first column aspect search terms.

Table 2 Parameters used in the Environmental Attitude literature search

	Aspects: combined with **AND**	
Synonyms: combined with **OR**	Environmental concern	Measur*
	Environmental attitude*	Assess*
	Environmental valu*	Analys*
	Environmental belief*	Survey*
	Environmental intention	Tool*
	Environmental willingness	Framework*
		Theor*
		Scale*
		Item*
		Instrument*
		Questionnaire*

Table 3 Parameters used in the Environmental Behaviour literature search

	Aspects: combined with **AND**	
Synonyms: combined with **OR**	Environmental behaviour*	Measur*
	Pro-environmental behaviour*	Assess*
	Environmental activit*	Analys*
	Environmental action*	Survey*
		Tool*
		Framework*

		Theor*
		Scale*
		Item*
		Instrument*
		Questionnaire*

Table 4 Parameters used in the Environmental Knowledge literature search

	Aspects: combined with **AND**		
Synonyms: combined with **OR**	Knowledge	Measur*	Environment*
	Understanding	Assess*	Sustain*
	Awareness	Analys*	
	Educat*	Survey*	
		Tool*	
		Framework*	
		Theor*	
		Scale*	
		Item*	
		Instrument*	
		Questionnaire*	

This search was conducted by searching the 'Topic' of literature in the core collection of Web of Science that includes title, keywords and abstracts. The 'environmental attitude' search (see Table 1) returned 7,558 records. As this literature review was focusing on review articles, the search was further refined to only include reviews. This further narrowed the search to 330 records. Screening the title, abstract and keywords of these records based on their relevance for purpose of this review resulted in a shortlist of 23 records. The 'environmental behaviour' search (see Table 3) returned 2187 records. When filtering for review articles, this was narrowed to 95 records. After screening the title, abstract and keywords of these records based on their relevance, a shortlist of 14 records remained. The knowledge assessment search was conducted twice, once without the third parameters ("Environment*" and "Sustain*"), in order to capture the wider literature of knowledge assessment, as well as that specifically relating to environmental knowledge. The wider 'knowledge assessment' search (see Table 4) returned 1013 records. When filtering for review articles, this was narrowed to 402 records. After screening the title, abstract and keywords of these records based on their relevance, a shortlist of 7 records remained. The more specific 'environmental knowledge' search (see Table 4) returned 702 records. When filtering for review articles, this was narrowed to 301 records. After screening the title, abstract and keywords of these records based on their relevance, a shortlist of 8 records remained.

In the next step, we searched the Wiley Online Library using the same set of keywords. This search was conducted on 3-4 March 2021. Searching the 'Topic' of literature is not possible in Wiley, therefore we searched the keywords within the abstracts of the records. To limit the search to review articles, the term 'article' was also searched for. Several of the same articles seen during WoS search were also seen in the Wiley search. These items were ignored and were not double counted. The 'environmental attitude' search returned 457 records that were similarly screened for relevance and resulted in a shortlist of 13 records. The 'environmental behaviour' search returned 360 records that were similarly screened for relevance and resulted in a shortlist of 13 records. The wider 'knowledge assessment' search returned 641 records that were similarly screened for relevance and resulted in a shortlist of 2 relevant records. The 'environmental knowledge' search returned 151 records that were similarly screened for relevance and resulted in a shortlist of 2 relevant record.

In total, the search of both Web of Science and Wiley resulted in a shortlist of 23 records for the 'environmental attitudes' search, 20 for the 'environmental behaviour' search and 18 for the 'knowledge assessment' search. Due to the inherent overlap between the environmental attitude and behaviour literatures, these two shortlists shared four of the same records.

3.2 Results – state of the art

There is considerable debate in the field of environmental attitude, knowledge and behaviour, particularly concerning the modelling and measurement of these concepts. Naturally, this has significant implications for MICS, particularly when assessing the impact of participation in Citizen Science.

3.2.1 Environmental Attitudes

Defining and conceptualising the terms 'environment' and 'attitude' (also termed 'environmental concern') occupies a large section of the literature in this field. In general, it is agreed that environmental attitudes are comparable to attitudes to other topics. There is now significant consensus that environmental attitudes are multi-dimensional, but reflect a single overall attitude to the environment (Dunlap & Jones, 2002). Cruz & Mantana (2020, p. 2) therefore term the concept "*a hierarchical attitude system that connects and organizes more specific attitudes about a range of environmental topics*". For example, in one of the fields seminal papers, Schultz (2001) highlighted three dimensions of environmental attitude: egoistic (concern for self), altruistic (concern for others), and biospheric (concern for the biosphere). Other dimensions have also been postulated by others. Furthermore, despite this general consensus of a hierarchical model of environmental attitude, there are scholars who conceptualise environmental attitudes differently. Dunlap & Jones (2002) highlight some papers which suggest that beliefs, intentions, and attitudes are strongly intertwined, and form a key part of (environmental) behaviour.

Difficulty in creating a unified definition and conceptualisation of 'environmental attitude' has led to issues with measuring it. These issues are widely reported, with some being directly caused by a poor definition of the term and invalid dimensions (Dunlap & Jones, 2002). Additionally, the methodology used when measuring environmental attitudes has also been the focus of a large portion of the literature. Self-reporting (in surveys and questionnaires) has been criticised by many, due to the inherent biases caused (Kormos & Gifford, 2014).

Considering this wide ranging conceptual and methodological debate, it is unsurprising that there is a plethora of available tools, methods and surveys available to measure environmental attitude. In a seminal review paper, Cruz & Mantana (2020) identified and examined 26 of the most commonly used scales, to identify the most valid. They identified the Ecology Scale from Maloney and Ward (1973) and Schultz's three-dimensional Scale (2001) as the most valid tools for measuring environmental attitudes.

However, arguable the most comprehensive and (currently) widely used scale is based on the New Ecological Paradigm (NEP) model (Dunlap & Catton, 1979; Dunlap et al, 2000). The NEP scale assesses attitude across a range of environmental topics, in addition to measuring beliefs, intentions and behaviours. This makes scales based on the NEP model highly practical when measuring environmental attitudes, as the model covers such a range of topics and concepts relating to attitudes. The NEP model has therefore resulted in a range of scales, which have been widely adapted within the field (e.g. Castro, 2006; Hawcroft & Milfont, 2010; Milfont & Duckitt, 2010).

Table 5 Environmental Attitude Assessment Literature Review

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Measurement of Environmental Concern: A Review and Analysis Cruz & Mantana (2020)	**Data collection:** - Questionnaire (Maloney and Ward's three-dimensional measure of ecological attitudes and knowledge (1973); Schultz's three-dimensional model, measuring biospheric, egoistic and social-altruistic concern (2001)) **Data type(s):** - Quantitative data	+ Both approaches are easily applicable, and require little investment or additional effort for implementation + Approach of Schultz (2001) has received multiple recent updates + Both approaches are 'traditional' and have been utilised often in the past + Approaches are relatively short - Both approaches highlighted are old, and have been recently updated	**Lessons learned** - Classic measures of environmental attitudes are still largely valid - Environmental attitudes are theorised to be multi-dimensional – scales and measurement tools should reflect this **Relevance for MICS** - Recommends scales of Maloney and Ward (1973) and Schultz (2001) as the most valid. Updates versions of these scales may provide useful tools
Two decades of measuring environmental attitudes: A comparative analysis of 33 countries Franzen & Vogl (2013)	**Data collection:** - Questionnaire (used longitudinally) **Data type(s):** - Quantitative data	+ Has been used globally and over a long period of time (and therefore can be used to reflect changes in attitude over time if applied multiple times) + Easily applicable for researcher and respondent, and requires little investment or additional effort for implementation - Uses often criticised self-report methodology - Approach conflates attitude with behaviour in several places	**Lessons learned** - Highlights that environmental attitudes are closely linked to socio-economic factors (such as wealth, employment, age etc.), and that some scales (such as the one utilised in this paper) can be used longitudinally to track changes in attitudes over time **Relevance for MICS** - Displays an approach that has specifically been used to track changes in environmental attitude over time
Behavior-based environmental attitude: Development of an instrument for adolescents	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Provides a tool able to measure both environmental attitudes and behaviour - Relatively long (three-part) questionnaire - Uses often criticised self-report methodology	**Lessons learned** - Suggests that attitude itself is not directly measurable, and must be measured via behaviour - Suggests that behaviour can be used to measure environmental attitude, and attitude can further be split into a multi-dimensional model (with 4-6 factors)

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Kaiser, Oerke & Bognor (2007)			**Relevance for MICS** - Attitude and behaviour could be measured using one single tool (as outlined in this study)
The Structure of Environmental Concern: Concern for Self, Other People and the Biosphere Schultz (2001)	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Approach is strongly grounded within traditional literature, investigating the classifications of environmental attitude + Short, easily applicable, and requires little investment or additional effort for implementation + Uses a strong, value-based survey to identifying environmental attitude + Results are mapped onto broader social-cognitive theory - Old approach, the tool has been further developed since this initial iteration	**Lessons learned** - Outlines a distinction between egoistic, altruistic, and biospheric environmental concerns **Relevance for MICS** - Multi-dimensional model of attitudes should be considered when measuring attitudes - One of the most commonly used or adapted measures of environmental attitude
Climate change in the Chinese mind: An overview of public perceptions at macro and micro levels Wang & Zhou (2020)	**Data collection:** - Questionnaires **Data type(s):** - Quantitative data	+ Several of the listed approaches and tools have been used to measure environmental attitude longitudinally - Little in depth analysis of approaches to measuring environmental attitudes (review is mostly a descriptive summary) - To date, the approaches highlighted have only been tested in China	**Lessons learned** - Age, gender, income, education, media use, personal experiences and socio-demographic characteristics are the main factors found to influence environmental attitudes, and should be considered when measuring environmental attitude **Relevance for MICS** - Key influences and factors for environmental attitudes highlighted - Approaches to measuring environmental attitude are of little relevance
Urban Sustainability and Smartness Understanding	**Data collection:** - N/A	+ In depth analysis of USSU (the relationship between human beings and the environment in which they live)	**Lessons learned** - Outline of key factors influencing the relationship between human beings and the environment. The

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
(USSU)—Identifying Influencing Factors: A Systematic Review Topal, Hunt & Rogers (2020)	**Data type(s):** - N/A	- Lacks a clear avenue for developing the framework into measurement/evaluation tool	factors identified: demographics; information and policy; (environmental) concerns; perceptions; infrastructure (physical and social); values; and actions **Relevance for MICS** - Key influences on environmental attitudes highlighted
What and where are environmental values? Assessing the impacts of current diversity of use of 'environmental' and 'World Heritage' values Reser & Bentrupperbaumer (2005)	**Data collection:** - N/A **Data type(s):** - N/A	- Approaches the topic from an abstract perspective (while useful, it does not help directly with the development of measurement/assessment tools)	**Lessons learned** - The precise meaning of 'environmental values' and other related terms are poorly understood, even by professionals working in the field. There is a need to better manage this discourse, and research and practice domain **Relevance for MICS** - Key definitions need to be clear before conducting analysis of attitudes - Little relevance for the development of a tool for measuring environmental attitude
Environmental Ethics Palmer, McShane & Sandler (2014)	**Data collection:** - N/A **Data type(s):** - N/A	+ Provides background of ethics and (in one section) environmental attitudes - Approaches the topic from an abstract perspective (while useful, it does not hold directly with the development of measurement/assessment tools)	**Lessons learned** - The precise meaning of 'environmental values' and other related terms are poorly understood, even by professionals working in the field. There is a need to better manage this discourse, and research and practice domain **Relevance for MICS** - Key definitions need to be clear before conducting analysis of attitudes - Little relevance for the development of a tool for measuring environmental attitude

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Human values and their importance to the development of forestry policy in Britain: a literature review O'Brien (2003)	**Data collection:** - N/A **Data type(s):** - N/A	+ Provides background of ethics and (in one section) environmental attitudes - Approaches the topic from an abstract perspective (while useful, it does not help directly with the development of measurement/assessment tools) - A large focus on the (forestry) policy implications of the review, but less discussion of the psychological aspects - Suggestion to hold workshops and focus groups to measure environmental attitudes and values would be time consuming and costly (compared to questionnaires)	**Lessons learned** - Deliberative approaches, such as workshops, focus groups and interviews, are needed to accurately evaluate people's environmental values **Relevance for MICS** - Holistic and multidisciplinary approaches to measuring environmental values and attitudes should be considered in any measure - Little relevance for the development of a tool for measuring environmental attitude
The ideological divide and climate change opinion: "top-down" and "bottom-up" approaches Jacquet, Dietrich & Jost (2014)	**Data collection:** - Questionnaire (Kahan et al, 2012) **Data type(s):** - Qualitative data	+ Considers interactions between social, psychological, and political factors in shaping environmental attitudes and behaviours - This review (as well as the study from Kahan et al (2012)) gives little detail on the actual questionnaire used to measure environmental attitude - Measures perceived environmental risk, this is not the same as environmental attitude	**Lessons learned** - Identifies key "top-down" and "bottom-up" factors contributing to the ideological divide concerning environmental values **Relevance for MICS** - Multi-dimensional model of attitudes should be considered when measuring attitudes - Approach is not relevant for measuring environmental attitudes
The relationship between materialistic values and environmental attitudes and behaviors: A meta-analysis	**Data collection:** - Questionnaire (Hodgkinson & Innes, 2001) **Data type(s):** - Quantitative data	+ Short, easily applicable, and requires little investment or additional effort for implementation + Measures environmental beliefs (in addition to broader questions) to better understand environmental attitude	**Lessons learned** - There is a significant association between materialistic values and both environmental attitudes and behaviours **Relevance for MICS**

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Hurst, Ditmar, Bond & Kassar (2014)		- Focuses on ecology (as well as environmentalism)	- Multi-dimensional model of attitudes should be considered when measuring attitudes, and should consider the role of values - Some aspects of the scale could be used to measure environmental attitude
Sustainability Knowledge and Attitudes – Assessing Latent Constructs Zwickle & Jones (2018)	**Data collection:** - Questionnaire **Data type(s):** - Qualitative data	+ Practical and applicable measure for environmental knowledge and attitudes: Assessment of Sustainability Knowledge (ASK) and the Sustainability Attitudes Scale (SAS) - Tools have not yet been widely tested	**Lessons learned** - Environmental attitudes and knowledge are intertwined **Relevance for MICS** - The scales outlined in the paper could be a useful tool for measuring environmental attitudes, but require further testing
The use (and abuse) of the new environmental paradigm scale over the last 30 years: A meta-analysis Hawcroft & Milfont (2010)	**Data collection:** - Questionnaire (New Environmental Paradigm Scale) **Data type(s):** - Quantitative data	+ Commonly used scale, that has been regularly tested in the past + Short (15 items), easily applicable, and requires little investment or additional effort for implementation - There is a lack of empirical and theoretical integration in studies employing this scale as a measure of environmental attitudes, which may mean that guidance for the use of this scale is hard to find - Little information about use of NEP to measure attitude changes over time	**Lessons learned** **-** NEP is a useful, widely used tool for measuring environmental attitude. However (as of 2010) few studies conducted broad analyses of NEP scales as a measure of environmental attitudes **Relevance for MICS** - Tools based on the NEP model offer potential approaches for measuring environmental attitudes
The environmental attitudes inventory: A valid and reliable measure to assess the structure of	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Considers and incorporates lessons learned from past scales to create a single unified approach	**Lessons learned** **-** Environmental attitudes can be claimed to have up to 12 dimensions, which should be reflected in measurement tools

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
environmental attitudes Milfont & Duckitt (2010)		+ Evidence suggests that it has high internal consistency, homogeneity and high test-retest reliability, - Relatively long (covering 12 different factors)	- Past scales had been well made, but (before this paper was released) the lessons learned from each have not been satisfactorily collated into a single usable scale **Relevance for MICS** - Combines lessons learned from many seminal papers in the field, to create a comprehensive scale
Embedded value systems in sustainability assessment tools and their implications Gasparatos (2010)	**Data collection:** - Questionnaire (Splash et al, 2009) **Data type(s):** - Quantitative data	+ Outlines the importance of measuring environmental attitudes as part of a wider process (in this case, broader sustainability assessments) - Approach is not specifically used to measure environmental attitudes, as such many items are not relevant - Not based on a widely used or accepted approach - Questionnaire is long and some items are relatively complex	**Lessons learned** - The values of the affected stakeholders should guide the selection of the appropriate sustainability evaluation tool **Relevance for MICS** - Provides some non-self-report items for measuring environmental attitudes
Some Psychological Aspects of Reduced Consumption Behaviour De Young (1996)	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Provides some basic understanding for key items that should be included when assessing environmental attitudes - Limited to consumption-related behaviour - Scales highlighted are relatively dated, and have been further developed in more recent studies	**Lessons learned** - A number of psychological concepts and phenomena (including intrinsic satisfaction and competence motivation) have a significant impact on consumption and environmental attitudes **Relevance for MICS** - Multi-dimensional model of attitudes should be considered when measuring attitudes - Article is relatively high-level, and does not provide concrete details about how environmental attitudes should be measured

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
The impact of direct and indirect experiences on the development of environmental knowledge, attitudes, and behavior Duerden & Witt (2010)	**Data collection:** - Mixed-methods **Data type(s):** - Quantitative and qualitative data	+ Methodology measures both environmental attitudes and environmental knowledge + Can be used to measure attitudes before and after and intervention - Time consuming qualitative methods used for some aspects of the approach + Provides insight into effect of particular experiences on environmental knowledge - Significant questions regarding the validity of approach due to lack of testing	**Lessons learned** - Environmental knowledge and attitudes play a significant role in the development of environmental behaviour - Experience type also plays a significant role on the development of environmental knowledge (indirect vs direct experiences) **Relevance for MICS** - Unified approach for measuring environmental knowledge, behaviour and attitudes suggests that it can be of use, but the approach outlined is too time consuming to be implemented simply
Increasing Nature Connection in Children: A Mini Review of Interventions Barrable & Booth (2020)	**Data collection:** - Workshop/exercise (e.g. Bragg et al (2003), based on the Inclusion of Nature in the Self theory (Schultz, 2002)) **Data type(s):** - Qualitative data	+ One of the few commonly used qualitative tools in the field, useful when working with children + Provides useful insight into how to measure environmental attitudes before and after an intervention - Uses the concept of ‘’nature connection’, (which is only a predictor of environmental attitude) - A significant portion of the review focuses on developmental psychology (due to the focus on childhood development)	**Lessons learned** - Simple to use qualitative tools are important depending on the participants involved **Relevance for MICS** - Useful literature on the impact of interventions on environmental attitudes - May be a useful tool for use with some participant groups
Environmental education outcomes for conservation: A systematic review	**Data collection:** - N/A **Data type(s):** - N/A	+ Provides some analysis of the various tools, interventions and experiences (with a focus on educational interventions) that can shape environmental attitudes, concerns and behaviours	**Lessons learned** - Nearly all environmental education programmes or interventions lead to some level of increase in a desirable, measured outcome (whether in attitudes, behaviour or direct environmental indicators)

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Ardoin, Bowers & Gaillard (2020)		- In general, the review looks at purely environmental indicators and outcomes of interventions (e.g. reduction of air pollution as a result of environmental education programmes), rather than the intermediary effects on attitude and behaviour	**Relevance for MICS** - Environmental education (and similar experiences) can impact on environmental attitudes
A Conceptual Framework for Understanding and Analysing Attitudes Towards Environmental Behaviour Barr & Glig (2007)	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Short and easy to implement - The measurement of attitudes only forms a small section of this approach - Approach has not been widely tested since its use in this study	**Lessons learned** - Pro-environmental behaviour is structured around people's everyday lifestyles (rather than being its own separate behaviour) **Relevance for MICS** - The lack of focus on attitudes alone (which is generally tied in to items about behaviour) suggests that other approaches may be more beneficial
Conjoint Analysis for Environmental Evaluation: A review of methods and applications Alriksson & Oberg (2008)	**Data collection:** - Questionnaire (Alvarez–Farizo and Hanley, 2002) **Data type(s):** - Qualitative data	+ Uses conjoint analysis (self-report of reaction to hypothetical situations) to assess environmental attitudes, building developing the method beyond its traditional area of market research - Focus on people as consumers / takes a marketing perspective - Scale does not exclusively focus on environmental attitudes	**Lessons learned** - Conjoint analysis has been used in the past to further understand environmental decision making (particularly focusing on natural resource use) **Relevance for MICS** - Conjoint analysis is a useful method/tool for evaluating environmental attitudes and values; however, its use is not currently as widespread as other methods
Energy saving in UK FE colleges: The relative importance of the socio- economic groups and environmental	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Also focuses on socio-economic influences of environmental attitudes - Niche focus on the business environment	**Lessons learned** - A range of socio-economic factors are significantly correlated with pro-environmental attitudes and behaviour (e.g. age) **Relevance for MICS**

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
attitudes of employees Al-Shemmeri & Naylor (2017)			- Socio-economic factors can influence environmental attitudes (and how attitudes change over time). They should therefore be measured and considered when drawing conclusions regarding the effect of participation in Citizen Science
Applying Social Psychology to the Study of Environmental Concern and Environmental Worldviews: Contributions from the Social Representations Approach Castro (2006)	**Data collection:** - Questionnaire (NEP) **Data type(s):** - Quantitative data	+ Highlights use of NEP globally	**Lessons learned** - Social representations theory can be useful to create a separation of attitudes from beliefs **Relevance for MICS** - Social representations theory has the potential to become the basis for measurement of environmental attitudes - NEP can form a useful tool for measuring environmental attitudes

3.2.2 Environmental Behaviour

Inherently, there is significant overlap between the fields of environmental behaviour and environmental attitude (as seen by the overlap of papers identified during the literature review), and separating the two from each other has proved difficult and contentious. As with environmental attitudes, dimensions of environmental behaviour have often been a source of disagreement in the literature. For example, there is still significant debate as to whether environmental behaviour is uni- or multi-dimensional (Kaiser and Wilson, 2004; Larson et al., 2015). For example, from their study of various pro-environmental behaviours, Kaiser and Wilson (2004) developed a six-dimensional model of behaviour (energy conservation, mobility and transportation, waste avoidance, consumerism, recycling, and vicarious conservation behaviours). Furthermore, a range of studies have also attempted to draw parallels between environmental behaviour and various personality traits, such as openness to experience (Brick and Lewis, 2016), cognitive flexibility (Lange and Dewitte, 2019), and tendency towards abstract thinking (Brick and Lewis, 2016). Regardless, it is generally agreed, however, that while environmental attitudes are linked to behaviour, strong pro-environmental attitudes do not necessarily lead to corresponding behaviours (as other influencing factors are often present). It is therefore necessary to measure the two separately, with separate scales.

One of the most significant recent developments in the field is the increasingly interdisciplinary nature of the research. Previously, psychology and sociology were relatively separated in this area, whereas current literature is now attempting to reconcile these disparate strands of research, and develop coherent frameworks. Batel et al. (2016) provide an in-depth review of this literature, highlighting how wider social changes can interact with psychological processes to influence environmental behaviour. In particular, they compare Social Representations Theory with Social Practices Theory and develop a wider theoretical model to understand behaviour change. This literature is also reinforced by research into how environmental behaviours are associated with broader changes in lifestyle and society (Scott et al., 2015).

The measurement of environmental behaviour (and the scales required to do so) has also generated a significant portion of literature. This can generally be done in three ways: observation in the field; laboratory observation; or self-reporting. Observation in the field has generally taken the shape of retrospectively assessing past behaviours, for example by analysing prior energy usage or transportation choices (Abrahamse et al., 2007). Laboratory observations generally refer to situations or choice-making within a controlled environment (Corral-Verdugo, 1997). However, these two methodologies are rarely used, with self-report questionnaires being the most used approach to measuring environmental behaviour. As with the measurement of environmental attitudes, there is significant debate around the validity of the self-report approach when assessing environmental behaviour. However, some recent studies have suggested that there is a significant correlation between self-reported and directly observed environmental behaviour (Kormos and Gifford, 2014), lending support to the use of such methodology. However, Kormos and Gifford (2014) also emphasised that a large portion of variance in the association between self-reported and objective behaviour remains unexplained, meaning that caution is required when utilising this approach.

Behavioural indicators (e.g. possession and usage of certain energy-using devices (Abrahamse et al , 2007; Gatersleben et al., 2002) and observation (e.g. Corral-Verdug, 1997).

Nevertheless, self-reporting is necessary for the majority of research in this field. The study from Kormos and Gifford (2014) analysed many of the most frequently used methodologies, and highlighted those most highly correlated with directly observed behaviour. Scales utilised by Kaiser et al. (2001), Vadez et al. (2003) and Corral-Verdugo and Figueredo (1999) appeared to provide the most valid results, suggesting that they may form a useful basis for future self-report studies of environmental behaviour. Kormos and Gifford (2014) also propose several suggestions for improving self-report scales – these lessons learned could be used to adjust and improve these past scales.

A further issue to consider is that environmental behaviour is not a single, monolithic concept, but is interdimensional (as previously stated). This is revealed when measuring behaviour. Several studies have suggested that individuals can be relatively inconsistent in environmental-related behaviour. For example, an individual may behave in an environment-friendly manner when it comes to dietary choices, but may often select environmentally damaging modes of transport (Gatersleben et al., 2002). Therefore, when measuring environmental behaviour (and making claims about the results of studies), one must be wary that a wide range of environmental behavioural dimensions are covered, or the scope of the study should remain context specific. Considering this, most current measures of environmental behaviour take a broad, general approach to measuring environmental behaviour, with a wide range of items.

Table 6 Environmental Behaviour Assessment Literature Review

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Exploring Urban Sustainability Understanding and Behaviour: A Systematic Review towards a Conceptual Framework Topal, Hunt & Rogers (2021)	**Data collection:** - N/A **Data type(s):** - N/A	+ Establishes new measures of sustainability understanding and behaviour assessment - Focus on urban sustainability (rather than broader picture) limits use of findings - Approach is not fully developed, only highlights the broad dimensions that should be considered (internal socio-psychological determinants, personality traits, and influencing external factors)	**Lessons learned** - Three clusters of factors contribute to environmental behaviour: (1) internal socio-psychological determinants, (2) personality traits, and (3) influencing external factors such as social, cultural, economic, and institutional factors - Attitude and behaviour should be measured separately – attitude does not predict behaviour (and vice versa) **Relevance for MICS** - Provides an explanation for how knowledge, attitudes and behaviour are interlinked, creating a visualisation for these interactions - No concrete approach for measuring behaviour proposed
Environmental education outcomes for conservation: A systematic review Ardoin, Bowers & Gaillard (2020)	**Data collection:** - Analysis of environmental indicators **Data type(s):** - Quantitative data	- Only environmental indicators are assessed (rather than the intermediary effects on attitude and behaviour), the scale of this approach is far too broad	**Lessons learned** - Nearly all environmental education programmes or interventions lead to some level of increase in a desirable, measured outcome (whether in attitudes, behaviour or direct environmental indicators) **Relevance for MICS** - Measurement of environmental behaviour via environmental indicators is not appropriate for MICS
Developing a critical agenda to understand pro-environmental actions: contributions from Social	**Data collection:** - N/A **Data type(s):** - N/A	+ Provides a useful critique, which can be applied to many psychological studies in this field (particularly focusing on assumption of causality)	**Lessons learned** - Highlights drawbacks in prominent schools of thought regarding social psychology - these drawbacks should be considered when reading all literature in the field

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Representations and Social Practices Theories Batel, Castro, Devine-Wright & Howarth (2016)		+ Gives an explanation of the impact of political systems and individualism (and individual responsibility) on environmental behaviours - No concrete approach for measuring behaviour proposed	**Relevance for MICS** - No concrete approach for measuring behaviour proposed, limiting relevance
Activation of social norms in social dilemmas: A review of the evidence and reflections on the implications for environmental behaviour Biel & Thøgersen (2007)	**Data collection:** - Questionnaires (Hopper & Nielsen,1991; Thøgersen, 2003; Vining & Ebreo, 1992; VanLiere & Dunlap, 1978; Heberlein & Black, 1976; Thøgersen,1999; Thøgersen & Ölander, 2006a; Grankvist, 2002; Black, Stern, & Elworth, 1985; Garvill, 1999; Hunecke, Blöbaum, Matthies, & Höger, 2001; Nordlund & Garvill, 2003) **Data type(s):** - Quantitative data	+ The tools considered are all embedded within rational choice theory, while measuring environmental behaviour + Most tools also consider the effect that social norms can have on moderating environmental behaviour - Approaches outlined in the paper are mostly outdated and very context specific (e.g. to evaluate participation in recycling programmes)	**Lessons learned** - Personal and situational factors are relevant for the activation of norms in social dilemmas **Relevance for MICS** - Approaches outlined are too context specific to be of general use – a combination of the tools may be required
The role of trust for climate change mitigation and adaptation behaviour: A meta-analysis Cologna & Siegrist (2020)	**Data collection:** - Questionnaires **Data type(s):** - Quantitative data	+ Global analysis (51 studies analysed from around the world) - Approaches only partly consider behaviour (trust in institutions forms the main section of the research)	**Lessons learned** - Trust in scientists and trust in environmental groups strongly correlate with climate-friendly behaviours (mostly for public, rather than private, behaviours) - Associations with trust in industry and general trust measures are weak **Relevance for MICS** - Trust in citizen science (and the wider scientific community) may influence behavioural outcomes - Outlined approaches are not fully relevant for measuring behaviour

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Encouraging pro-environmental behaviours: A review of methods and approaches Grilli & Curtis (2021)	**Data collection:** - Questionnaires and observation **Data type(s):** - Quantitative and qualitative data	+ Qualitative alternatives to measuring behaviour are identified - Little concrete information on behaviour measurement approaches themselves (more focus on intervention methods)	**Lessons learned** - Selection of 'intervention' should be based on specific objectives, desired outcomes and target population; organisation of the 'intervention' has more of an effect than the type of treatment itself **Relevance for MICS** - The tool for measuring environmental behaviour is not concretely developed, the paper only outlines the appropriate behavioural dimensions for measurement
Science education for environmental awareness: approaches to integrating cognitive and affective domains Littledyke (2007)	**Data collection:** - N/A **Data type(s):** - N/A	- Little concrete information on behaviour measurement approaches themselves (more focus on intervention methods)	**Lessons learned** - A sense of relationship is essential for environmental care, meaning that cognitive and affective domains need to be explicitly integrated in environmental education - For citizen science to impact behaviours, projects need to foster a sense of belonging, as well as sharing information about the environment **Relevance for MICS** - Approach focuses more on the intervention itself, rather than measuring behavioural outcomes – as such this tool is not applicable
A Conceptual Framework of the Adoption and Practice of Environmental Actions in Households	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Gives a specific focus to a neglected area of research: household decision making literature - Approach contains little concrete information on how it should be applied	**Lessons learned** - The social context of the household and day-to-day life (as also suggested by Barr & Glig (2007)) has a significant impact on environmental behaviours **Relevance for MICS**

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Scott, Oates & Young (2015)			- Approach needs to be better defined and outlined before use
Encouraging pro-environmental behaviour: An integrative review and research agenda Steg & Velk (2009)	**Data collection:** - Behavioural indicators (e.g. possession and usage of certain energy-using devices (Abrahamse et al (2007); Gatersleben et al., (2002)) and observation (e.g. Corral-Verdugo (1997)) **Data type(s):** - Quantitative data	+ Removes confounding factors innate to self-report and questionnaire methods - Complex and time-consuming methodologies - Some tools require access to personal data (e.g. on energy use)	**Lessons learned** - Behavioural interventions are generally more effective when they are systematically planned, implemented and evaluated **Relevance for MICS** - Measurement of behavioural indicators is often seen as the 'gold standard' for assessing behaviour, however its measurement is complex and not realistic for MICS
Informational strategies to promote pro-environmental behaviours: Changing knowledge, awareness and attitudes Abrahamse & Matthies (2012)	**Data collection:** - Questionnaire (e.g. Staats et al, 1996) **Data type(s):** - Quantitative data	+ Approach is used to give before and after intervention measurements (useful for tracking change in behaviour over time) - There are more updated versions of the questionnaires outlined	**Lessons learned** - In the current state-of-the-art, the five most common behavioural intervention methods are: provision of information, goal setting, commitment, prompting and feedback **Relevance for MICS** - Implementation of before and after intervention measurement may be relevant for assessing behaviour change over time
A Conceptual Framework for Understanding and Analysing Attitudes Towards Environmental Behaviour Barr & Glig (2007)	**Data collection:** - Self-report questionnaire **Data type(s):** - Quantitative data	+ In addition to measuring behaviour through self-report, several composites of behaviour are also measured (including willingness, psychological variables, social and environmental values etc) - Short and easy to implement - Approach has not been widely tested since its use in this study	**Lessons learned** - Pro-environmental behaviour is structured around people's everyday lifestyles (rather than being its own separate behaviour) **Relevance for MICS** - Provides a promising approach for measuring environmental behaviour, but has not been tested for validity

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
The impact of direct and indirect experiences on the development of environmental knowledge, attitudes, and behavior Duerden & Witt (2010)	**Data collection:** - Mixed-methods **Data type(s):** - Quantitative and qualitative data	+ Methodology measures environmental behaviour, as well as knowledge and environmental attitudes + 'Experience-based' approach to measuring environmental behaviour + Can be used to measure behaviour before and after intervention - Time consuming qualitative methods used for some aspects of the approach - Significant questions regarding the validity of approach due to lack of testing	**Lessons learned** - Environmental knowledge and attitudes play a significant role in the development of environmental behaviour - Experience type also plays a significant role on the development of environmental knowledge (indirect vs direct experiences) **Relevance for MICS** - Unified approach for measuring environmental knowledge, behaviour and attitudes suggests that it can be of use, but the approach outlined is too time consuming to be implemented simply
Values, identity and pro-environmental behaviour Gatersleben, Murtagh & Abrahamse (2014)	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Short, easy to implement + Behaviours are broken down into: intention, attitude and perceived behavioural control (aiming to capture the whole behavioural process) - Self report methodology - Uses very few items to measure behaviour – only 5 types of environmental behaviour are assessed	**Lessons learned** - The findings lend support for the concept of identity campaigning to promote sustainable behaviour - Identity is a significant predictor of intention to perform pro-environmental behaviours **Relevance for MICS** - A more thorough approach to measuring behaviour should be identified
The Environmental Psychology of the Ecological Citizen: Comparing Competing Models of Pro-Environmental Behavior	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Easy to implement, and well-grounded in theory - Approach is relatively narrow, and focuses only on individuals' private lifestyle choices	**Lessons learned** - Compares and combines two models of environmental behaviour: the value-belief-norm theory (Stern et al., 1999) and the ecological citizenship model (Dobson, 2003) **Relevance for MICS**

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Jagers, Martinsson & Matti (2016)			- If the approach can be adapted and used to measure broader environmental behaviour, it could be of relevance
Protection motivation theory and pro-environmental behaviour: A systematic mapping review Kothe, Ling, North, Klas, Mullan & Novoradovskaya (2019)	**Data collection:** - N/A **Data type(s):** - N/A	+ In-depth analysis of the Protection Motivation Theory, and its application to predicting and changing pro-environmental behaviours - No concrete tool for measuring environmental behaviour is outlined	**Lessons learned** - Protection Motivation Theory is a useful framework to allow researchers to understand what factors contribute to pro-environmental behaviours **Relevance for MICS** - Protection Motivation Theory can be used as a basis for developing environmental behaviour measures; however, no such tool is outlined
Cognitive Flexibility and Pro-environmental Behaviour: A Multimethod Approach Lange & Dewitter (2019)	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	- Relatively complex compared with other tools - Use of unreliable self-report methodology	**Lessons learned** - The relationship between cognitive flexibility and pro-environmental behaviour did not reliably extend to the level of performance tasks **Relevance for MICS** - The approach to measuring environmental behaviour is relatively minimalist compared with others (as behaviour only formed part of this study)
Pro-environmental behavior: Rational choice meets moral motivation Turaga, Howarth & Borsuk (2010)	**Data collection:** - N/A **Data type(s):** - N/A	+ Identifies the value-belief-norm model as key when measuring environmental behaviour - Work is currently highly theoretical, no concrete tool is proposed with which to measure environmental behaviour	**Lessons learned** - Social norms and moral motivation suggest that empowering individuals to perform pro-environmental behaviours (rather than external actors assuming this role) **Relevance for MICS** - No concrete tool is identified with which to measure environmental behaviour

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
How do I see myself? A systematic review of identities in pro-environmental behaviour research Udall, de Groot, de Jong & Shankar (2019)	**Data collection:** - Questionnaires and observations **Data type(s):** - Quantitative data	+ Provides a framework for the measurement of identities regarding changes in environmental behaviour - Theoretical elaboration without practical tool	**Lessons learned** - Identity (and particular types of identify) can significantly influence participation in pro-environmental behaviour **Relevance for MICS** - Lacks a coherent, overarching tool to measure environmental behaviour
The validity of self-report measures of pro-environmental behavior: A meta-analytic review Kormos & Gifford (2014)	**Data collection:** - Questionnaires (with a focus on Kaiser et al, 2001; Vadez et al, 2003; and Corral-Verdugo & Figueredo, 1999) **Data type(s):** - Quantitative data	+ The three most discussed approaches (out of the larger review set) are commonly used (particularly in the case of Kaiser et al (2001)), relatively short and easily utilised + Approaches are highly valid - Some of the outlined approaches are context specific and may require adjustment - Approaches are relatively dated, and more updated versions have been developed (e.g. Kaiser, 2020)	**Lessons learned** - Self-report methodology significantly correlated with directly observed behaviour; however, a large amount of variance remains unexplained **Relevance for MICS** - The three approaches found to be most valid in this meta-analysis provide a promising avenue for environmental behaviour measurement

3.2.3 Assessment of Knowledge and Environmental Knowledge

The literature on the assessment of knowledge and learning outcomes is comprehensive, and has often been grounded in broader frameworks of learning. The key goals of learning (and thus assessment) have been captured in Blooms Taxonomy (1956): knowledge, comprehension, application, analysis, synthesis, and evaluation. These goals each represent a different level of learning and understanding; assessments should therefore be designed to identify at which level a person is operating. While there have been new taxonomies developed since Bloom's Taxonomy (for example, that of Koedinger et al. (2012)), these are the key concepts which still ground learning and assessment.

The fundamental goal of the assessment of learning has been conceptualised in a variety of ways, but the definition from Blythe et al (1998, p. 63) is one of the most commonly cited: "*Performances of understanding require students to show their understanding in an observable way. They make students' thinking visible. It is not enough for students to reshape, expand, extrapolate from, and apply their knowledge in the privacy of their own thoughts…Such an understanding would be untried, possibly fragile, and virtually impossible to assess*".

Assessment of knowledge should not simply be seen as a 'one way street', however. Although assessment has long been seen as a 'normative' process, many argue should be ongoing or formative, providing students with feedback about their work and also allowing both teacher and students to assess progress towards understanding (Baird et al., 2017). Watling and Ginsburg (2019) highlight how assessment is a learning opportunity for those taking part, as well as for instructors or teachers. It should allow for feedback and an understanding of how to improve learning in the future.

While the broader knowledge assessment literature sheds much needed light on the theoretical background of learning outcome measurement, the literature is largely based on research within academic settings, and is aimed at improving assessment within schools. It is also largely theoretical and does not highlight particular tools or scales that could be used to measure learning from participation in citizen science. For this reason, a further search was conducted focusing on the measurement of environmental knowledge.

The majority of the literature into environmental knowledge has been written with the aim to assess the influence of knowledge on environmental behaviours. It is generally accepted that environmental knowledge contributes to sustainable or environmentally-conscious behaviour (Heimlich and Ardoin, 2008; Roczen et al 2014), but that knowledge alone does not lead to this behaviour (Frick et al, 2004). A portion of the literature goes further than this debate, and investigates how environmental knowledge itself can be measured, and how environmental knowledge can change over time.

Traditionally, the educational and psychological fields split knowledge into declarative knowledge (factual knowledge) and procedural knowledge (skills that transform declarative knowledge into action (Anderson, 1976). Frick et al (2004) further developed these dimensions, and specified them for environmental knowledge: system knowledge (e.g. understand the basic structural and functional characteristics of an ecosystem); action-related knowledge (e.g. understand solutions for environmental issues); and effectiveness knowledge (e.g. understand the benefit of sustainable actions). This framework is now commonly used, and lends itself to environmental studies, as it allows the assessment of environmental core knowledge, as well as knowledge relevant for achieving behavioural goals related to sustainability (which is often the desired outcome of a training or intervention).

Braun and Dierkes (2019) used these measures to create a framework with which to assess environmental knowledge before and after an intervention. In the study, the framework was used to measure various areas of environmental knowledge (e.g. water, conservation, renewables, etc.) in a group of participants before and after an intervention. This multi-dimensional framework and approach to environmental knowledge measurement has also been successfully implemented in a similar study by Liefländer et al. (2015). Both of these studies have developed similar tools with which to measure environmental knowledge, which can be used and adapted for future studies of environmental knowledge, including in the context of citizen science projects.

A further challenge in (environmental) education is to determine the best way in which knowledge can be self-reported. It is common in environmental research to use confidence or agreement ratings that self-report one's own knowledge, i.e., "I can explain what the term ecology means," (Duerden and Witt, 2010). It is often suggested that these tests do not measure actual knowledge, and are more just a representation of subjective knowledge (Metcalfe, 1996). More direct knowledge assessment tools are now used more frequently.

Table 7 (Environmental) Knowledge Assessment Literature Review

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Reviewing assessment of student learning in interdisciplinary STEM education Gao, Li, Shen & Sun (2020)	**Data collection:** - N/A **Data type(s):** - N/A	+ Two dimensions essential for knowledge measurement are identified - Framework currently lacks an explicit knowledge measurement tool - Context specific to STEM and academic setting	**Lessons learned** - Assessment should consider the nature of the domain of learning, as well as knowledge, skill, practice, and affective domains **Relevance for MICS** - No concrete assessment tool is presented
The Knowledge-Learning-Instruction Framework: Bridging the Science-Practice Chasm to Enhance Robust Student Learning Koedinger, Corbett & Perfetti (2012)	**Data collection:** - N/A **Data type(s):** - N/A	+ Clear theory of learning assessment developed, which builds on past frameworks (e.g. Blooms taxonomy) - Little information present about assessment and analysis of knowledge - No application of framework as of yet	**Lessons learned** - There are three broad types of learning events: memory and fluency processes; induction and refinement processes; and understanding and sense-making processes - Presents an alternative to Bloom's Taxonomy, focusing on the knowledge needed to achieve objectives through cognitive process terms **Relevance for MICS** - No concrete assessment tool is presented
Targeted Assessment of Students' Interdisciplinary Work: An Empirically Grounded Framework Proposed	**Data collection:** - Literature review **Data type(s):** - Qualitative data	+ Clear theory of learning assessment developed - Little information present about assessment and analysis of knowledge - No application of framework as of yet - Specific to learning and knowledge transfer in the academic setting	**Lessons learned** - Assessment tasks should invite students to build and demonstrate understanding of "whole"; and assessment should be on-going **Relevance to MICS** - Clear framework for learning presented, but no concrete assessment tool linked to this framework is offered

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Boix Mansilla and Duraising (2007)			
Science education for environmental awareness: approaches to integrating cognitive and affective domains Littledyke (2007)	**Data collection:** - Drawing (e.g. Driver et al, 1985) **Data type(s):** - Qualitative	+ Highlights alternative methods for measuring scientific (and environmental) knowledge through drawing - Little concrete information on behaviour measurement approaches themselves (more focus on intervention methods) - Time consuming and complex to analyse results (compared to self-report methods	**Lessons learned** - Environmental education is a vital in developing pro-environmental behaviour (particularly in children) **Relevance for MICS** - More information needed on how to conduct and analyse the results are needed
A systematic review of trends and findings in research employing drawing assessment in science education Chang, Lin, Lee, Lee, Lin, Tan & Tsai (2020)	**Data collection:** - Drawing/observation **Data type(s):** - Qualitative data	+ An alternative, non-traditional manner of assessing knowledge - Specific focus on children and young participants - Time consuming and difficult to interpret results	**Lessons learned** - Drawing can be used to assess knowledge **Relevance for MICS** - Such assessment methods could be used to assess the impact of participation in citizen science (particularly for young children)
Consideration of a Bayesian Hierarchical Model for Assessment and	**Data collection:** - N/A **Data type(s):** - N/A	+ Outlines use of ongoing assessments of knowledge, to measure progress over time (or effects of interventions) - Little information present about assessment and analysis of knowledge	**Lessons learned** - Being able to draw knowledge curves is a vital aspect of understanding knowledge gain over time **Relevance for MICS**

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Adaptive Instructions Kim & Ritter (2019)		- No application of framework as of yet	- Outlines how ongoing assessments can be beneficial to understanding knowledge gain, but does not offer a tool with which to measure this
Toward coherence in curriculum, instruction, and assessment: A review of learning progression literature Jin, Mikeska, Hokayem & Mavronikolas (2019)	**Data collection:** - Literature review **Data type(s):** - Qualitative data	+ Applies the learning progression approach to long term learning goals and assessment	**Lessons learned** - Learning progression (descriptions of the successively more sophisticated ways of thinking about a topic) approaches are crucial for scientific understanding **Relevance for MICS** **-** Learning progression approaches have significant implications and contributions to knowledge assessment, particularly when evaluating knowledge gain over time
Personal understanding and target understanding: Mapping influences on the outcomes of learning Entwistle & Smith (2010)	**Data collection:** - N/A **Data type(s):** - N/A	+ Develops a practical theory of learning within education that summarises some of the major influences on the outcomes of learning - Concrete knowledge measurement tool is not outlined - Focus on learning outcomes, rather than the actual assessment of learning	**Lessons learned** - Suggested an updated taxonomy for evaluating learning outcomes: mentioning; describing; relating; explaining; and conceiving **Relevance for MICS** **-** Updated taxonomy can be used to develop knowledge measurement tools, but the tool itself is not developed in this paper
Ethics and Fairness in	**Data collection:** - Survey	+ Highlights many frequent pitfalls for commonly used assessment tools	**Lessons learned**

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Assessing Learning Outcomes in Higher Education Zlatkin-Troitschanskaia, Schlax, Jitomirski, Happ, Kühling-Thees, Brückner & Pant (2019)	**Data type(s):** - Quantitative data	- Context specific to academic settings - The tool outlined is at a meta level – it assesses knowledge assessment, rather than knowledge itself	- Many commonly used standard assessment tools are unethical or unfair for certain groups. Steps need to be taken to ensure equal chance when measuring learning outcomes **Relevance for MICS** **-** Highlight rules for ensuring fairness when assessing learning outcomes - The tool could be used to assess knowledge assessment approaches, but it use for assessing knowledge itself is limited
Assessment and learning: fields apart? Baird, Andrich, Hopfenbeck and Stobart (2017)	**Data collection:** - N/A **Data type(s):** - N/A	+ Directly links theories of learning to learning outcome assessments - Concrete knowledge measurement tool is not outlined	**Lessons learned** - To develop more accurate assessments (which actually measure the goals of education), theories of learning and assessment should be developed in tandem **Relevance for MICS** **-** Concrete knowledge measurement tool is not outlined, but lessons from the paper are important for developing such a tool for MICS
Theory and Learning Analytics Knight & Shum (2017)	**Data collection:** - N/A **Data type(s):** - N/A	+ Details a simple set-by-step process to selecting/designing a knowledge assessment tool - Does not present a knowledge assessment tool itself	**Lessons learned** - All analytics tools implicitly express a commitment to a particular educational worldview – the evaluator must be conscious of this - Key questions to ask when selecting/designing a knowledge assessment tool: What are we measuring; how are we measuring; why are we measuring; who are we measuring; where are we measuring'; when are we measuring **Relevance for MICS**

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
			- Important lessons are presented for a knowledge assessment tool to be developed (for example, specifically for citizen science)
Assessment, feedback and the alchemy of learning Watling & Ginsburg (2019)	**Data collection:** - N/A **Data type(s):** - N/A	+ Highlights the formative role of assessment; assessment and feedback should be used to shape the learning process - Context specific – focus on academic setting (particularly medical education) - Concrete knowledge measurement tool is not outlined	**Lessons learned** - Assessment and feedback should be used to shape the learning process **Relevance for MICS** - Outcomes of assessment should be utilised by citizen science projects in order to improve learning opportunities - No concrete knowledge measurement tool is outlined
Evaluating Three Dimensions of Environmental Knowledge and Their Impact on Behaviour Braun & Dierkes (2019)	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Practical, easy to implement tool + Can be used to measure knowledge before and after intervention + Built on previously successful tools (e.g. Liefländer et al, 2015) - Relatively weak correlations found with some dimensions of tool	**Lessons learned** - Development of multi-dimensional model of environmental knowledge: action-related; system; and effectiveness. **Relevance for MICS** - Tool developed to measure several areas of environmental knowledge could be adapted by MICS
Evaluating Environmental Knowledge Dimension Convergence to Assess Educational Programme Effectiveness	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Practical, easy to implement tool + Can be used to measure knowledge before and after intervention	**Lessons learned** - Development of multi-dimensional model of environmental knowledge: action-related; system; and effectiveness. **Relevance for MICS** - Tool developed to measure several areas of environmental knowledge could be adapted by MICS

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Lieflaender, Bogner, Kibbe & Kaiser (2015)			
The impact of direct and indirect experiences on the development of environmental knowledge, attitudes, and behavior Duerden & Witt (2010)	**Data collection:** - Mixed-methods **Data type(s):** - Quantitative and qualitative data	+ Methodology measures both environmental knowledge as well as environmental attitudes + 'Experience-based' approach to measuring environmental knowledge + Can be used to measure knowledge before and after intervention - Time consuming qualitative methods used for some aspects of the approach + Provides insight into effect of particular experiences on environmental knowledge - Significant questions regarding the validity of approach due to lack of testing	**Lessons learned** - Environmental knowledge and attitudes play a significant role in the development of environmental behaviour - Experience type also plays a significant role on the development of environmental knowledge (indirect vs direct experiences) **Relevance for MICS** - Unified approach for measuring environmental knowledge, behaviour and attitudes suggests that it can be of use, but the approach outlined is too time consuming to be implemented simply
Environmental knowledge and conservation behavior: exploring prevalence and structure in a representative sample Frick, Kaiser & Wilson (2004)	**Data collection:** - Questionnaire **Data type(s):** - Quantitative data	+ Items based upon widely accepted three-dimension model + Approach measured environmental behaviour as well as environmental knowledge - Dated method, more recent tools have developed this approach	**Lessons learned** - Action-related knowledge and effectiveness knowledge have a direct effect on environmental behaviour **Relevance for MICS** - Presents a useful (if dated) approach to measuring environmental knowledge

Reference	Methodological approach	Strengths (+) & weaknesses (-) of approach	Lessons learned/ Relevance for MICS
Sustainability Knowledge and Attitudes – Assessing Latent Constructs Zwickle & Jones (2018)	**Data collection:** - Literature review **Data type(s):** - Qualitative data	+ Practical and applicable measure for environmental knowledge and attitudes: Assessment of Sustainability Knowledge (ASK) and the Sustainability Attitudes Scale (SAS) + Successfully applies and tests new scales to past theories of environmental knowledge + Tools take a broader view of environmental knowledge, focusing on environmental, economic, and social areas - Tools do not follow past three domain approach to environmental knowledge - Tools have not yet been widely tested	**Lessons learned** - Environmental knowledge is a broad concept and includes environmental, economic, and social domains **Relevance for MICS** - The scales outlined in the paper could be a useful tool for measuring environmental attitudes and knowledge
Insights for Measuring Environmental Awareness Ham, Mrčela & Horvat (2015)	**Data collection:** - N/A **Data type(s):** - N/A	+ A clear outline and review of the current state of the art in environmental awareness and knowledge - No concrete tool is outlined or suggested	**Lessons learned** - There are currently three main issues in the field: issues in measuring different components of attitude (cognitive, affective and conative component), issues concerning the attitude – behaviour gap and issues concerning the influence of social desirability and the research sample **Relevance for MICS** - Details some potential avenues for linking environmental knowledge and attitudes - No concrete tool is outlined or suggested

3.3 Best practice indicators and approaches for assessing attitudes, knowledge and behaviour

As highlighted in the previous section, there is a plethora of information and research regarding the measurement of environmental attitudes, behaviour and knowledge. Yet this literature (and the approaches and tools developed within it) has not yet been fully incorporated into the field of Citizen Science. Data has been collected from individuals that have engaged in Citizen Science activities in the past (Randi Korn, 2010), and several past studies have even investigated the impact of engagement with citizen science on attitude (Bonney et al. 2009) behaviour and knowledge (Tweddle et al. 2012). Building on these individual and isolated studies, Kieslinger et al (2017) presented one of the most complete frameworks for evaluating the impact of Citizen Science on participants. This framework outlines three dimensions of the participatory scientific processes: *scientific dimension*; *Citizen Scientist dimension*; and *socioecological/economic dimension* (based on Holocher-Ertl and Kieslinger (2015)).

Despite this comprehensive framework, specific measures, scales and tools for measuring these dimensions were not identified by Kieslinger et al (2017). The analysis of the literature review in section 3.2 has led to the identification of a number of indicators and approaches for measuring environmental attitudes, behaviour and knowledge which have been included in the MICS conceptual Framework in the society dimension.

One of the central discussions in the field is whether these concepts should (or even can) be measured with a single, unified tool or approach. Several theories, such as the Theory of Planned Behaviour (Ajzen, 1991), suggest that attitudes (which are made up of beliefs) are closely related to behaviour, while evidence has also suggested that knowledge and attitudes are linked (Zwickle & Jones, 2018). However, despite these relatively high-level psychological theories linking these attitudes, behaviour and knowledge, the literature focusing on environmental psychology generally separates the concepts. Therefore, the tools and approaches identified in this literature review are generally specific to measuring one of the three concepts: environmental attitudes, environmental behaviour, or environmental knowledge.

In the field of **environmental attitude**, there is (to a large degree) currently a consensus on the most valid tools to use when measuring attitude. As outlined in section 3.2.1, there are a range of tools that have been used to measure environmental attitudes. Over the history of the literature, the field has been relatively fragmented, with studies often creating new scales with which to measure environmental attitudes. Despite this, the three most commonly used (and adapted) scales are the Ecology Scale from Maloney and Ward (1973), Schultz's three-dimensional Scale (2001) (see Annex 2) and the New Ecological Paradigm (NEP) scale (Dunlap & Catton, 1979; Dunlap et al, 2000). These scales (along with other prominent scale in the field) and the attitudinal dimensions that they identified, have been incorporated into the most comprehensive tool currently available in the field, the Environmental Attitudes Inventory (EAI) (Milfont & Duckitt, 2010). The EAI (see Annex 1) offers a 12-dimensional approach to measuring environmental attitudes, has been used across a range of contexts and has been found to be highly consist and reliable.

Several other more tools have been developed recently, and show promise in the measurement of environmental attitudes. One of the most prominent of these is the Sustainability Attitudes Scale (SAS) (Zwickle & Jones, 2018). This scale used the three-domain definition of sustainability, looking at attitudes to: Ecological Sustainability; Social Sustainability Subscale; and Economic Sustainability. While testing of this scale generally been found it to be valid, it is still relatively new and has not been used as extensively as other scales. Additionally, SAS measures 'sustainability attitudes', rather than ‘environmental attitudes’. While there is a large amount of overlap between the two, this should be considered when selecting a scale. Despite these flaws, this scale could offer a possible tool for measuring environmental attitude within Citizen Science in the future.

Considering the state of the literature, the current use of attitude measurement scales, and the particular needs for Citizen Science, the Environmental Attitudes Inventory (EAI) (Milfont & Duckitt, 2010) was identified as the most applicable for measuring environmental attitudes within Citizen Science. Despite the length of the scale, there are several shortened versions of the inventory that can also be utilised. Due to its prevalence across the literature, strong validity, and short, simple nature, Schultz’s Three Dimensional Scale (2001) was identified as an alternative tool.

A variety of best practices and tools are also used in the field of measuring **environmental behaviour**. However, the comprehensive study by Kormos and Gifford (2014) listed three tools that stand out above others. The tools utilised by Kaiser et al. (2001), Vadez et al. (2003) and Corral-Verdugo and Figueredo (1999) each have benefits for measuring environmental behaviour, and importantly appear to be highly valid when doing so. However, the scales from both Vadez et al. (2003) and Corral-Verdugo and Figueredo (1999) are highly context specific (measuring behaviour relating to deforestation and recycling respectively). The scale used by Kaiser et al. (2001) – which was adapted from the “General Measure of Ecological Behaviour” (Kaiser, 1998) – covers a range of different behaviours, and achieved the highest degree of validity in this large study.

Variants of the Kaiser et al. (2001) scale have been often adopted by following researchers in the field. The most updated of these tools is the ‘General Ecological Behavior Scale - 50’ (Kaiser, 2020) (see Annex 3). This tool is generally the most widely used when measuring environmental behaviour, as well as being the most flexible (in terms of the various behaviours and dimensions assessed). For this reason, it provides the most promise to those attempting to measure environmental behaviour within Citizen Science.

There is also little consensus regarding best practice when measuring **environmental knowledge**. One of the most commonly used frameworks is the three-dimensional theory of environmental knowledge, separating knowledge into system, action-related and effectiveness dimensions. Assessment should therefore reflect these dimensions. The tool used by Braun and Dierkes (2019) (see Annex 4) does this well, and can measure environmental knowledge across a broad range of topics. This tool therefore can be easily adapted to measure environmental knowledge within Citizen Science. An alternative scale could be the Assessment of Sustainability Knowledge (ASK) (Zwickle and Jones, 2018) (see Annex 5). As this scale was developed alongside the Sustainability Attitudes Scale (SAS), use of both tools would allow for the measurement of environmental knowledge and attitude using the same theoretical framework. However, neither have yet been widely tested.

4 MICS conceptual framework

The draft MICS conceptual framework is composed of three different levels of abstraction:

- the overarching impact domains;
- the intervention logic; and
- the identified conceptual and practical approaches for indicators within each domain.

These are addressed in the sub-sections below, respectively.

4.1 The MICS impact domains

MICS considers the impacts of citizen science in five distinct, yet interlinked, impact domains[1]:

- *Society:* Impact on society and individuals as well as collective (societal) values, understanding, actions and well-being (including relationships).
- *Economy:* Impact on the production and exchange of goods and services among economic agents; on entrepreneurial activity; economic benefits derived from data, e.g. for the public good or for the benefit of private sector actors.
- *Environment:* Impact on the bio-chemical-physical environment, e.g. on the quality or quantity of specific natural resources or ecosystems.
- *Science and technology:* Impact on the scientific process (method) as well as research more broadly; on the scientific system (institutions; science policy; incentive structures), scientific paradigms and resulting technological artefacts (e.g. sensors, apps, platforms) and standards.
- *Governance:* Impact on the processes and institutions through which decisions are made, both informal and formal (e.g. public policy), and on relationships/partnerships, as well as the governance of data generated.

While the three interlinked domains of sustainable development (environment, society and economy) are well-known and accepted, the context of citizen science warrants the focus on two additional domains, namely science and technology, and governance. The science and technology domain is considered due to citizen science's alignment with, and use of the scientific process and resulting (potential) implications for the scientific system, scientific paradigms and technological artefacts. An additional governance domain is considered owing to the links of citizen science processes and results to monitoring, (environmental) management and (public) decision-making processes. These impact domains arguably cut across many if not all of the Sustainable Development Goals (SDGs). Moreover, considering impacts in different domains is helpful for 'unpacking' them, drawing attention to and enabling analysis of distinctly different types of impacts, e.g. those to the physical environment [environment] as compared to those to institutional settings [governance]. Nevertheless, impacts in the different domains can be closely connected and may occur in sequence - interdependence even - rather than in parallel. For example, Wehn et al., 2020b showed that case-specific changes in society (e.g. sense of place) and governance (e.g. improved support for participation in decision making) are required before envisaged changes in the environment can be attained (e.g. improved air quality).

[1] This section draws on Wehn et al. (2021) which was published by MICS partners during the production of this deliverable.

4.2 Holistic intervention logic

The intervention logic (also known as results chain or logical framework approach) is behind many impact assessment efforts of public interventions and - in particular – the assessment of *research* activities, namely the MoRRI framework (Monitoring Responsible Research & Innovation RRI) (Ravn et al., 2015) as well as evaluations of citizen science efforts (e.g. DITOS consortium, 2016). This logic considers an intervention (e.g. a given program or project) in terms of its **objectives**, **inputs**, **activities**, **outputs**; the use or application of the resulting outputs may lead to **outcomes** or changes that are beyond the immediate sphere of control of the intervention (van Es et al., 2015). Such changes may be (un)desired and/or un(expected) and the extent of their obtainment may be affected positively or negatively by contextual or external factors.

The 'richer' version of this intervention logic, also called holistic intervention logic, namely the Theory of Change (ToC), is argued to strengthen the (otherwise difficult) case for attributing observed outcomes or changes to a given intervention or its actions (Blamey and Mackenzie, 2007; Dhilon and Vaca, 2018) since it requires not only the specification of the intervention elements listed above, but also the articulation of **intermediate steps, assumptions, hypotheses** and **assumed causal relations** underlying the intervention's design and how envisaged changes may be achieved. Moreover, the ToC draws attention to the importance of capturing (comprehensively) the context of interventions that, ultimately, aim to trigger changes (of people, organisations or even systems) and to the fact that perspectives on 'what needs to change and why' (van Es et al., 2015, p. 13) may differ.[2]

As argued in MICS deliverable D2.2 (Wehn, et al., 2020a), the Theory of Change stands out for its structure for both, impact assessment and guidance towards achieving impacts, alongside the realisation of what is (and what is not) under immediate control of the intervention or project (i.e. the spheres of control, influence and interest, see illustration in Figure 1). Impact assessments of citizen science initiative have already revealed the 'nested' and sequential nature of changes across impacts domains, for example, environmental changes are conditional on social and institutional changes in managing the natural resource(s) in focus of the citizen science initiative (Wehn et al., 2020b). The MICS conceptual framework will therefore allow users to specify and capture layered and related intermediary outcomes along **impact pathways that cut across different MICS impact domains**.

[2] As a project management tool, one of the strengths of the ToC is to trigger discussion early on among project partners/participants on the intended changes, their rationale and (different/parallel) means to achieve them.

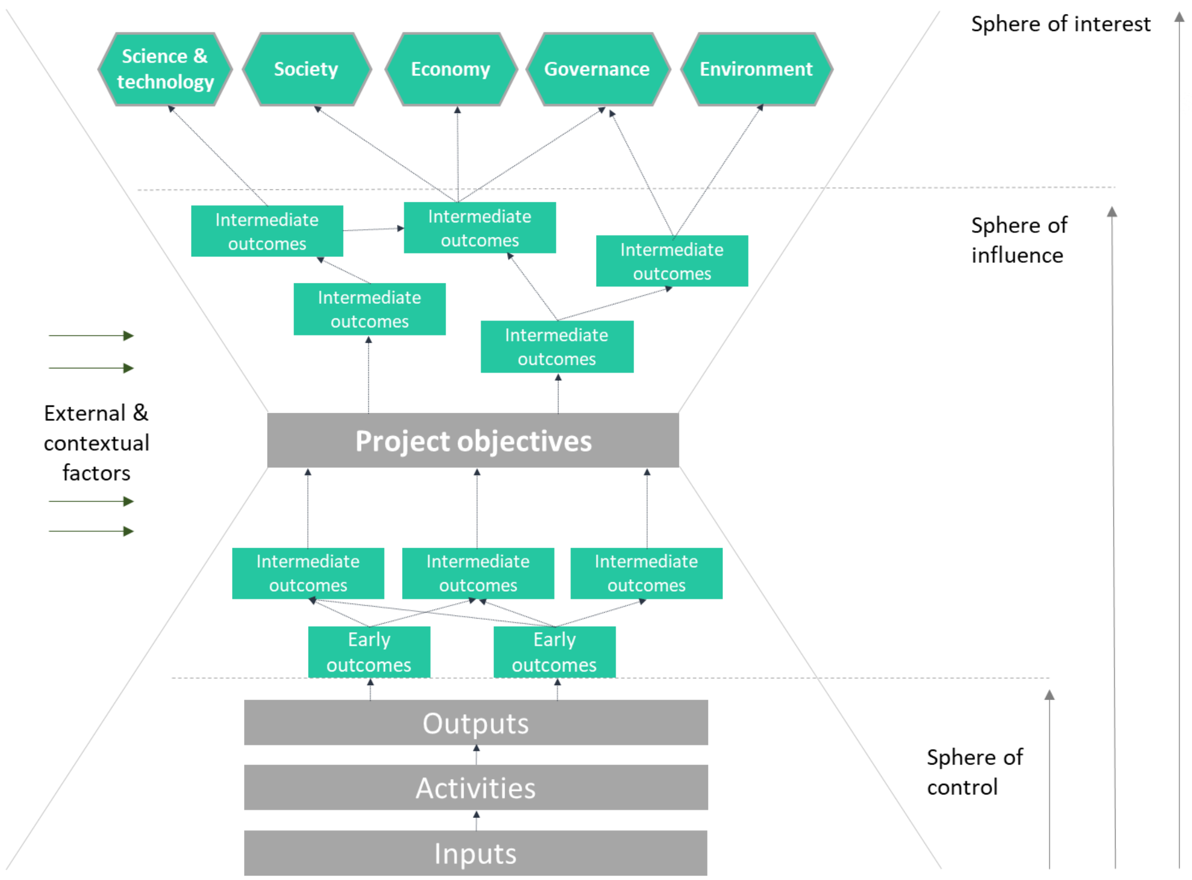


Figure 1 Theory of change elements

Source: Compiled from Van Es et al. (2015)

A considerable number of impact assessment efforts in the citizen science field (20 out of the 77 publications in this review) draws attention to the need to consider *comprehensively* the **context** of a given citizen science initiative, the **process** or means by which it is being implemented and, last but of course not least, its impacts. Along with this comes the understanding that impact assessment is a 'moving target' in the sense that the results of one stage or phase of project implementation generate new realities, and hence a changed context. For the MICS conceptual framework, this results in demands for comprehensively capturing the initial situation and the (evolving) context and, hence, an enhancement of the project information sheet presented in Annex 1 of MICS deliverable D2.4 to include relevant context-related parameters. Similarly, process indicators are considered alongside outside and impact indicators.

4.3 Indicators & methods

To complete the MICS conceptual framework, specific indicators and methods per impact domain serve as the basis for capturing progress with achieving specific outcomes and impacts. The results of the comprehensive review of existing literature on indicators are available in Annexes 6-10 and consists of 83 indicators.

Specifically, this consists of an organised set of indicators per domain, whereby thematically-related or even overlapping indicators have been clustered (see Table 8). This serves as a reference work of currently existing indicators for capturing process- as well as results-related aspects of citizen science projects. In line with the holistic intervention logic and hence the tailored approach to impact assessment of citizen projects outlined in section 4.2, these indicators can be drawn upon and combined selectively, as appropriate for the specific impact logic of a given citizen science project.

Table 8 Overview of indicators and clusters per domain

Domain	Indicator Cluster	Indicator Name
Society	Individual level	Individual development
		Individual learning outcomes
		Environmental knowledge
		Sustainability Knowledge
		Individual learning outcomes
		Capacities (skills and competences)
		Value creation
		Individual learning
		Individual and societal impacts
		Participation and opportunities for learning
		Involvement and support
		Experience and efficacy
		Individual and societal outcomes
		Awareness, and knowledge of a resource
		Pro-environmental attitude
		Environmental motives
		Ecological Behavior
		Individual outcomes
		Transformative change
	Meso-level	Organizational outcomes
		Community building
		Dissemination and feedback
		Community engagement and participation
		Citizen-led research
		Participatory dynamics
	Societal level	Social and cultural characteristics of a resource
		Social inclusion
		Social capital
		Societal outcomes
		Societal outcomes related to human health
		Societal outcomes
		Societal knowledge exchange outcomes
		Societal impact
		Distribution of risks
		Environmental risk perception
	Science & society	Public engagement in science

		Civic action, identity and activism Public understanding of science Scientific knowledge and attitude change
	Access to Information	Information
	Capacity building & education	Capacity building Awareness and responsibility Environmental education and stewardship
Domain	**Indicator Cluster**	**Indicator Name**
Science & Technology	**Data collection and management**	Data Data and systems Enhanced data
	Collaboration in science	Collaboration and synergies Scientific impact Community participation in research
	Contribution to science	Scientific contribution (1) Scientific contribution (2) Scientific value of data Written material Knowledge democracy Scientific objectives
	Decision making	Management and Policy Scientific outcomes
	Communication and outreach	Communication material Science initiatives & events Evaluation and adaptation
Domain	**Indicator Cluster**	**Indicator Name**
Governance	**Participation**	Participation dynamics Institutional commitment to public engagement
	Power dynamics	Power dynamics within CS initiative Change in power relations
	Impact on policy	Institutional setup Contributions to management plans and policy Shift in policy and regulations Change in policies & practices
	Equality and inclusion	Gender equality
Domain	**Indicator Cluster**	**Indicator Name**
Environment	**Natural resources and biodiversity**	Biodiversity of flora, fauna and landscapes Biophysical and geographical characteristics of natural resources Quality of natural resources/ fighting pollution
	Environment & society	Environmental impact on human health* (env. conditions) Natural and socio-cultural capital

	Ecosystem and resilience	
Domain	**Indicator Cluster**	**Indicator Name**
Economy	**Supply side**	Company growth
		International trade & investment
		Innovation & research
		Competitiveness
		Economic potential and market opportunities
	Demand side	Employment
		Conduct of business
		Value added for organizations

Despite the advanced progress of this work to date, it is also important to point out limitations. For one, the indicator set needs to be further analysed for thematic gaps, e.g. in response to 'demand' for indicators from the MICS case studies, that are not yet covered. This implies additional work on deriving indicators from relevant scientific fields of study. Secondly, as is evident from Table 9[3], despite the vast range of thematic aspects covered by the current set of indicators, many of these required either substantial resources to be implemented (19 indicators are considered resource demanding, 24 moderately resource demanding to implement) or the information provided in the literature is insufficient to operationalise and apply specific indicators (this is the case for 20 indicators).

Table 9 Summary of # of indicators per domain and their feasibility

Domain	Thematic clusters of indicators	Indicators	Feasibility (# of indicators)				
			Resource demanding (RD)	Moderately RD	Slightly RD	Minimal resources required	Insufficient information to judge
Society	6	43	9	16	0	6	12
Science & Technology	5	17	0	4	1	6	6
Governance	4	9	3	3	3	0	0
Environment	2	6	0	1	2	2	1
Economy	2	8	7	0	0	0	1
Total	19	83	19	24	6	14	20

[3] As explained in section 2.2, the assessment of the feasibility of the implementation of each indicator was done by considering the proposed data collection methods, sources and maturity of data collection items as well as indicator building specification. The feasibility of indicator was categorised as either resource demanding, moderately resource demanding, slightly resource demanding or minimal resources required. Indicators that missed information in the fields used to assess the feasibility were categorised as 'insufficient information to judge'.

5 Application of the MICS conceptual framework in the MICS case studies

The application of the MICS conceptual framework in the MICS case studies includes three main steps and a number of processes. This section is dedicated to describing these steps and processes, along with examples from application of the MICS conceptual framework in the MICS case studies. In summary, these steps consist of the following:

- **Step 1 - Context analysis** is dedicated to reflecting on the context in which a citizen science project is being established. Identifying pathways of change and articulating desired outcomes and impacts is not possible without a thorough understanding of the context. The documentation of the co-design process of the MICS case studies using the case study co-design compendia served to provide an understanding of the social, institutional, economic, environmental and technological context of the MICS cases. As a part of this step, revisiting, reflecting on, and where needed updating documentation of the contextual setting enabled a shared understanding among the team members involved in the impact assessment of each case. This is described in detail in section 5.2.

- **Step 2 - Design and validation of a Theory of Change (Impact Journey)** is the most elaborate step in the IA process and focuses on the design of the ToC (also referred to as Impact Journey, for ease of communication with stakeholders) for each MICS case study. This step includes the identification of relevant domains of change, expected impacts, and expected outcomes; formulating strategies for achieving desired changes; determining cause – effect relationships, and documenting casual assumptions. The practical steps taken for development of the ToC in the MICS case studies is described in detail in section 5.3.

- **Step 3 - Planning, Monitoring, Evaluation, and Learning (PMEL)** focuses on developing a practical and flexible plan for motoring and evaluation of the MICS case study, based on the indicators of the MICS conceptual framework. The practical steps taken for selecting relevant indicators for the MICS case studies is described in detail in section 0.

5.1 Guidance for the application of the MICS conceptual framework

The application of the MICS conceptual framework consists of a step-by-step approach to identify and monitor pathways of change, i.e. so-called impact journeys for each case study. Dedicated guidance was developed by WP2 in the form of a generic Impact Assessment compendium that provides instructions for the process as well as dedicated structures to capture the results of the activities. This guidance was applied in all case studies of the project in WP4, in collaboration with case study leads and members of the MICS team. Each case study team completed a compendium for their respective case study.

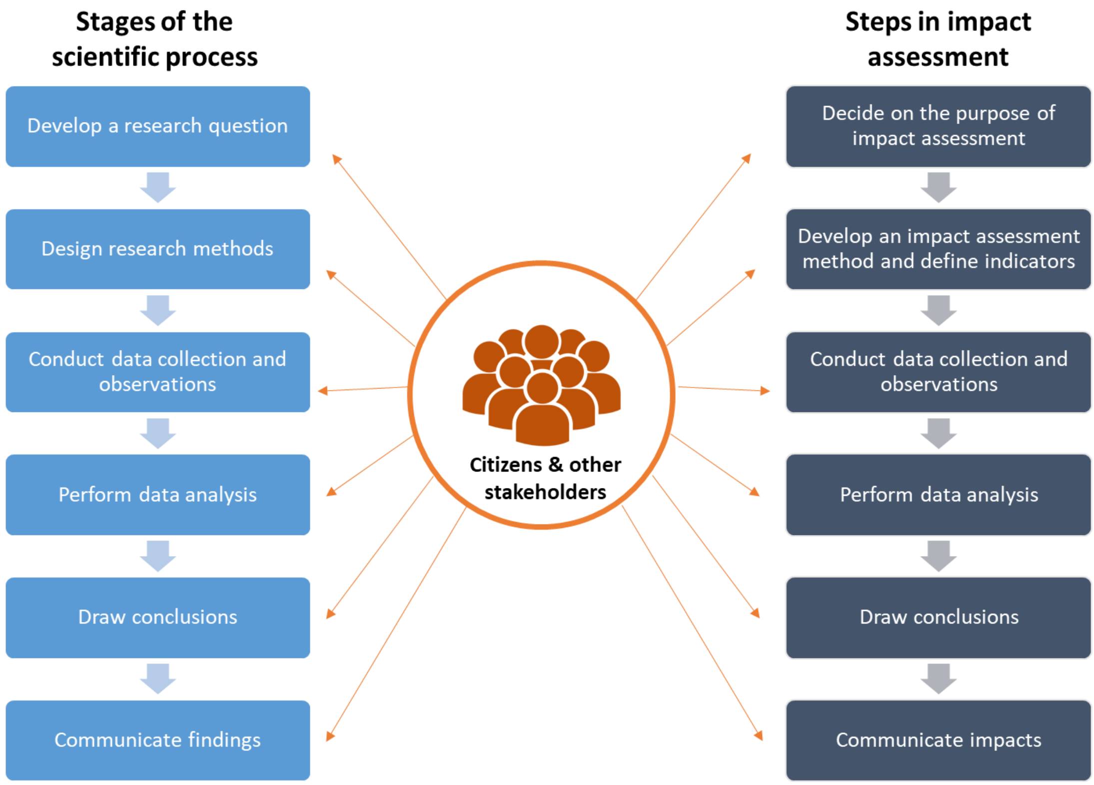
The MICS process to work with this compendium was as follows:

1. WP2 leader, IHE Delft, prepared instructions for the MICS case studies.
2. Case study leads used their respective compendium to follow the steps and fil in the document over time. This ensured all information is easily accessible for all tasks in MICS, without the need for much coordination.

3. The progressive completion of the compendium fed into and was undertaken during the regular case study team teleconferences and discussions.

The MICS approach to assessing the impacts of citizen science includes the realisation that, similar to citizen science which allows for participation of the general public in the scientific processes, it is possible for citizens and other stakeholders who are not typically participating in the impact assessment process to provide inputs for, or participate in, the impact assessment process (see Figure 2 Involvement of citizens and other stakeholders in citizen science and impact assessment) . Arguably, citizen scientists are well-placed to inform and judge the evolving impacts of their citizen science activities.

Figure 2 Involvement of citizens and other stakeholders in citizen science and impact assessment



Application of the MICS conceptual framework therefore was an effort that involved collaborations and interactions among the MICS team in each case study, and with local stakeholders in the cases. The citizen scientists, community members and other stakeholders in each case study were involved. This involvement entailed the joint identification and agreement of priority outcomes and impacts, of suitable indicators as well as joint data collection, analysis and interpretation (of selected) indicators. It also entailed adjustment and simplification of selected terminology to avoid scientific 'jargon': instead of ToC, the team referred to 'impact journey'; outcomes and impacts were referred to as 'short term impacts' and 'long term impacts' instead.

In some cases, there was a need for smaller task forces to work on a specific task and report back to all team members in a plenary setting. The Miro.com platform was used as an interactive tool to design the ToCs of the case studies in a collaborative and visual way. Using this tool, the ToCs were designed as a digital board that included the building blocks of a ToC (i.e. activities, outputs, outcomes and impacts, impact domains), and the links between these elements (see section 5.2.4 for an example).

Validation of the ToCs was done by designing and organizing stakeholder workshops in each case study. During these workshops, local stakeholder also decided which indicators of change were most important to monitor, and how to monitor those indicators (i.e. monitoring strategies). The application of the guidance for the MICS conceptual framework is further elaborated in sections 5.1, 5.2, and 5.3, along with examples from the MICS case studies.

The three main steps for identifying and monitoring pathways of change using the MICS conceptual framework were provided for the case studies in the form of instructions, work sheets and guidelines which are summarised below in sections 5.2-5.4. Each step includes of a number of activities that need to be completed before advancing to the next stage.

5.2 Step 1 - Context analysis in the MICS cases

Main objective of this stage:

The main objective of this step was to ensure that the context of each case study is well-understood and taken into account when designing the ToC for the case. Conducting a thorough context analysis can be an extensive exercise that requires a lot of time and resources. The idea at this stage is not to conduct an extensive exercise, but to make sure that the assumptions and causal relationships that are central to the ToC are based on well-documented and up to date in-formation. This of course depends on available time and resources of CS projects.

Details:

The first action for the team at this step was to revisit and reflect on the information about the of the case that had been recorded as a part of the co-design process in the case study, following the guidance provided in MICS deliverable D4.6. This included information about social, institutional, economic, environmental and technological contextual settings, stakeholders at different levels, and potential additional sources of information about the context.

Table 10 presents an example of a table that was completed as a part of this action in the Outfall Safari case of MICS. In case after revisiting the information about the context of the case study, the team concluded that additional information about the context needed to be collected, then the team would discuss practical aspects about completion of the information.

Table 10 Reflection on the need for additional information about the context of the Outfall Safari case study, UK

Information	Complete	Date of status assessment	Up-to-date
Social, institutional, economic, environmental and technological contextual settings	Complete	16/10/2020	Up to date
Stakeholders and at different levels	Complete	16/10/2020	Up to date
Additional sources of information about the context [if applicable - please clarify]	Websites with Outfall Safari Guides & Resources: https://catchmentbasedapproach.org/learn/outfall-safari-guide/ https://www.zsl.org/conservation/regions/uk-europe/londons-rivers	19/11/2020	Up to date
Additional sources of information about the context [if applicable - please clarify]	-	-	-

In case time and resources do not allow for conducting an extensive context analysis, there are a number of available resources that can be consulted to map different contextual aspects. Table 11 provides an overview of some of these available sources.

Table 11 Available sources of information for context analysis

Data source	Provider	Domain of relevance	Link
The Indicators We Want	UNDP[1]	Governance	https://www.undp.org/content/undp/en/home/librarypage/democratic-governance/the-indicators-we-want.html
The Global Risks Reports	WEF[2]	Governance, Environment	https://www.weforum.org/reports
Eurostat	EC[3]	Environment, Governance, Society, Economy	https://ec.europa.eu/eurostat/web/regions/data/database
Global SDG Indicators Database	UN[4]	Environment, Governance, Society, Economy	https://unstats.un.org/sdgs/indicators/database/
OECD Environmental Performance Reviews (by country)	OECD[5]	Environment	https://www.oecd.org/environment/country-reviews/
OECD Better Life Index: Environment	OECD[5]	Environment	http://www.oecdbetterlifeindex.org/topics/environment/
Regional Social and Environmental indicators	OECD[5]	Environment	https://stats.oecd.org/Index.aspx?DataSetCode=REGION_SOCIAL

The Institutional Profiles Database (IPD)	IPD[6]	Society	http://www.cepii.fr/IPD.asp
OECD Social Indicators, 'society at a glance'	OECD[5]	Society	https://www.oecd-ilibrary.org/social-issues-migration-health/society-at-a-glance_19991290
OECD, Measuring the Information Economy	OECD[5]	Society, Economy	https://www.oecd.org/digital/ieconomy/measuringtheinformationeconomy2002.htm
Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators	UN-GGIM[7]	Environment, Governance, Society, Economy	http://ggim.un.org/knowledgebase/KnowledgebaseArticle51479.aspx
Education at a Glance 2014: OECD Indicators	OECD[5]	Society	https://www.oecd.org/education/Education-at-a-Glance-2014.pdf
OECD Social Indicators, 'society at a glance'	OECD[5]	Society	https://www.oecd-ilibrary.org/social-issues-migration-health/society-at-a-glance_19991290
OECD Better Life Index	OECD[5]	Society	http://www.oecdbetterlifeindex.org/#/11111111111

[1] United Nations Development Programme, [2] World Economic Forum, [3] European Commission, [4] United Nations, [5] Organisation for Economic Co-operation and Development, [6] The Institutional Profiles Database, [7] United Nations Initiative on Global Geospatial Information Management

5.3 Step 2 - Development and validation of the Theory of Change in the MICS case studies

This step relates to the process that led to the development and validation of the ToC in each case study.

Main objective of this stage:

The main objective of this step is to map the desired/envisioned elements of change related to the case study's citizen science activities, i.e. outcomes and impacts, as well as strategies that are required to make these changes happen. Creating a visual representation of the ToC also requires clarifying cause and effect relationship between strategies, outcomes and impacts. "*A Theory of Change is a hypothesis of how we think change occurs*"[4]. Therefore, a key activity of this step is to identify and document the assumptions that are made while conducting this mapping exercise.

5.3.1 Identifying the desired/envisioned domains of change

Not all Citizen Science initiatives aim at having (or will have) impact in all five domains (i.e. science & technology, society, environment, economy, and governance). Therefore, identifying the desired/envisioned domains of change was an initial part of this step in developing a ToC for each case. It is important to be realistic/selective and choose the domains that the citizen science project plans to have the most impact on. For example, Table 12 shows a screenshot of the IA compendium of the MICS Hungarian case study (Creek Rákos) that shows this case focuses on three of the impact domains, namely society, environment and governance, as well as the rationale for focusing on each domain.

[4] AfriAlliance Consortium, (2017, p.9)

Table 12 Desired/envisioned domains of change in the Creek Rákos case study, Hungary

Domain	Rationale
Science & technology	Not a primary impact domain.
Society	Raising awareness of the society and changing their attitude to environmental issues in their neighbourhood such as Creek restoration can help creating the supportive understanding in the society for the ecological restoration and citizens will pay more attention and take care of their environment, what they learn better and take on a steward role for the Creek.
Environment	Describing (in some occasions at a layman's term) our environment, the ecosystem status / baseline is key for the ecological restoration and for making the areas protected.
Governance	Improving awareness and capacities of the decision-makers brings them closer to the implementation of ecological restoration. Pressure coming from the civil sector and the deeper level of the involvement of the local society makes the governance system move towards higher level of transparency, accountability
Economy	Not a primary impact domain.

5.3.2 Identifying long-term changes (impacts) and short-term changes (outcomes)

After the desired domain(s) of impact were identified, specific expected long-term changes (impacts) and short-term changes (outcomes) needed to be identified respectively. Long term impacts refer to changes that are expected to happen because of an intervention (i.e. here the citizen science initiative), in an approximate time frame of 10 years. Outcomes or short-term/mid-term changes refer to changes that are expected to happen because of an intervention, in an approximate time frame of 3-5 years. It is OK to be ambitious and make assumptions, but identified impacts should not be unrealistic, their achievement should not be impossible, and assumptions made need to be thoroughly documented.

Expected impacts and outcomes of each case were identified either with local stakeholders (e.g. in the Outfall Safari case study) or discussed only among the case study team members (e.g. Rakos Creek). This was done using key guiding questions such as:

- *What are the desired/intended impacts and outcomes per domain that the project wants to achieve or contribute to?*
- *Why are these intended impacts/outcomes important to achieve?*
- *How are these intended impacts/outcomes achieved?*
- *For whom are these impacts/outcomes important and why? And what are the assumptions made for identifying the selected impacts/outcomes?*

Table 13 presents an example of expected impacts on society in the Romanian case study of MICS (Carashuat Wetland).

Table 13 Example of expected impacts in the Carashuat Wetland case study, Romania

MICS domains of impact	What are the desired/intended impacts (long-term changes) per domain that the project wants to achieve or contribute to?	Why are these intended impacts important to achieve?	For whom are these impacts important and why?	What are the assumptions made for identifying the selected impact(s)?
Society	To increase the stakeholder's awareness of the impact of pollution on the environment (with focus on the biodiversity)	The stakeholders can develop a network that can act as guardians of the new created wetland in helping to preserve and improve its conditions	DDBRA: - Improve the local knowledge about the environment status and improve the biodiversity; - Help developing a monitoring plan with the help of CS activities; Local authority: - Provide support for increasing the local biodiversity, as an instrument for increasing eco-tourism	Increase the level of involvement for the DDBRA, Local Authority and citizens

5.3.3 Development of initial ToC

Every intervention will have pathways of change of how to bring the desired future about, consisting of the logical cause and effect relationships between the building blocks of a ToC i.e. strategies, assumptions, activities, outputs, outcomes and impacts. In order to identify and document these relationships, MICS case study teams organized a number of internal meetings per case study. Miro.com was used as an interactive tool to discuss and visualize the ToC. This resulted in identifying pathways of change i.e. the cause-effect relations between your strategies, outcomes and impacts, and development of an initial version of ToC per case study. An example an initial ToC for the Romanian case study is presented in Figure *3*.

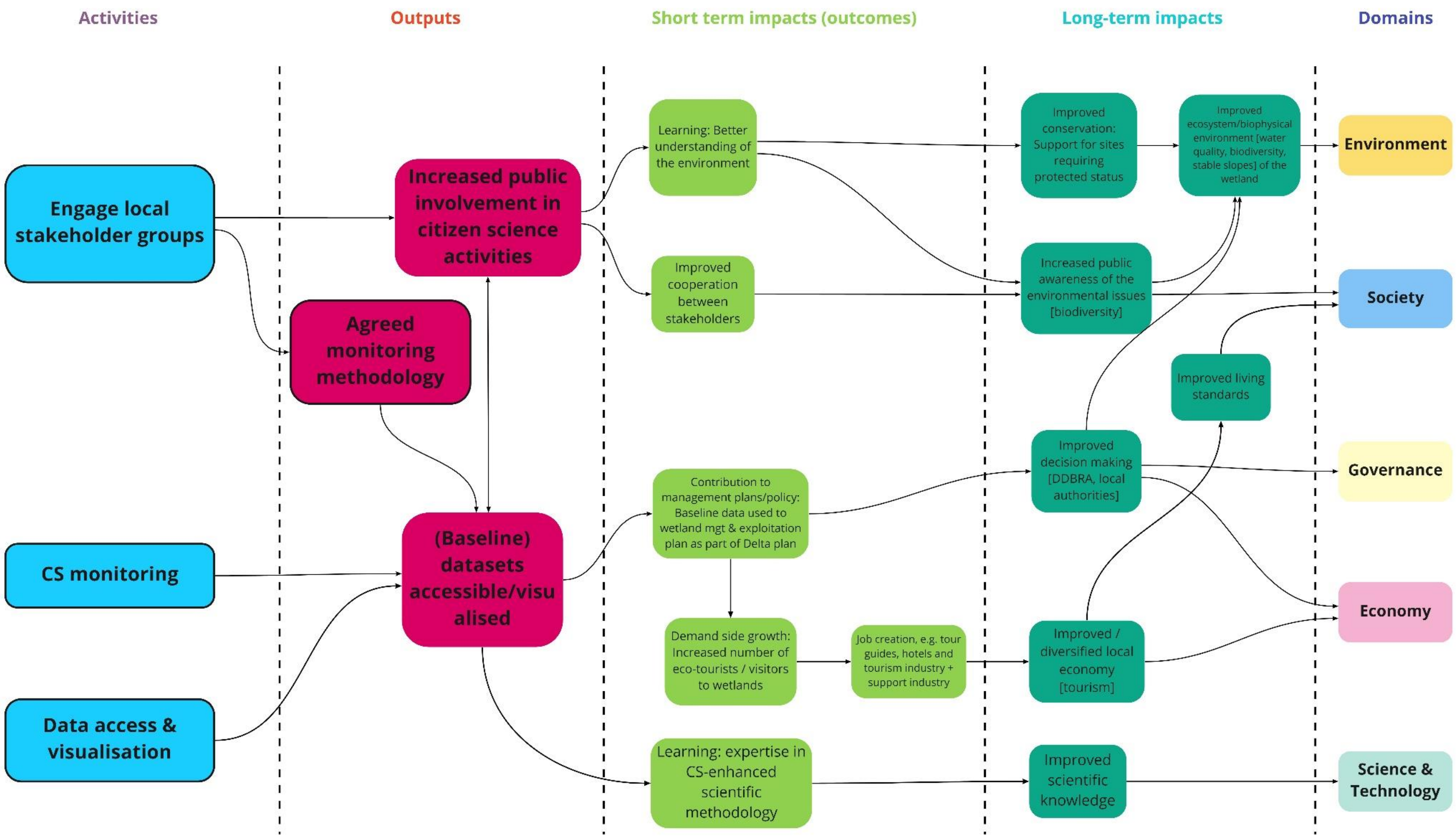


Figure 3 Example of an initial version of ToCs – the Carashuat Wetland case study, Romania

5.3.4 Formulation of strategies for achieving desired changes

This part includes the formulation of strategies for achieving outcomes and impacts. Strategies are a general description of what the MICS case study needs to do in order to make the expected outcomes happen. Engaging certain stakeholders that can help achieving the envisioned short-term or long-term changes, training volunteers, or the development of necessary tools are example of typical strategies in a CS initiative. More specific activities for each MICS case study were identified by each case study team. Table 14 presents an example of formulated strategies in the Hungarian cases study of MICS.

Across the MICS case studies, the following generic strategies were used:

- *Fostering stakeholder Engagement*
- *From Data to Knowledge*
- *From Data to Action*
- *Driving future project development*
- *Enhancing the community*

Table 14 Example of formulated strategies in the Creek Rákos case study, Hungary

What are the planned strategies for achieving the desired/intended outcomes?	Which actors are responsible for (or involved in) executing the strategies?	What resources are required for executing the strategies?	What are the assumptions made for adopting the strategies?
Strategy 1 **Engagement of key stakeholders**	Responsible: NGOs (e.g. GREEN XVII), Involved: NGOs (Hun. Biodiv. Research Soc.), citizens (including schools), local municipality (district 17), Budapest municipality	Human capacities for carrying out awareness raising activities for the citizens, and financial resources for practicing a diverse communication (media campaign, videos, events, flash mobs etc), lobbying with decision makers for engaging them, formal and informal network	- Stakeholders are interested - There is a social and political acceptance of (or trust in) the initiator (us) and the initiative - Resources are available (human capacities, financial resources for activities, time etc.)
Strategy 2 **From data to restoration commitment**	Responsible: NGOs (e.g. GREEN XVII), Involved: NGOs (Hun. Biodiv. Research Soc.), citizens (including schools), local municipality (district 17), Budapest municipality	Resources (human, financial, expertise) to process and visualize the data and communicate the results, lobbying with decision makers for gaining their commitment, formal and informal network	- Collected data is credible (the quality, quantity and type of collected data is sufficient enough for making decisions re. Restoration) - The communicated data and visualizations are clear, understandable and targeted - There is a social and political acceptance of (or trust in) the initiator (us) and the initiative - Decision-makers make commitment based on the data collected

5.3.5 Document causal assumptions

Assumptions underlying a ToC help explain why and how proposed activities and adopted strategies are expected to lead to identified impact pathways and result in certain (desired) outcomes and impacts. Assumptions should be checked with evidence from research, good practices, or the shared (professional or local) experience of the actors involved. Assumptions supported by evidence still need monitoring during implementation to ensure that they are also valid in this particular context. Table 15 presents an example of assumptions that were identified by citizen scientists and project managers during the workshops of the Outfall Safari case study. As the table shows, project managers and citizen scientists identified quite a number of shared assumptions.

Table 15 Example of assumptions made in the Outfall Safari case, UK

Assumptions	Citizen Scientists	Project managers
Funding is available	✓	✓
Non-monetary resources are available (e.g. time, IT)	✓	✓
Local stakeholders are willing to be engaged	✓ incl. Youth and non-CS	✓
Rivers are accessible	✓	✓
Water companies take action	✓	✓ Team available to manage misconnections
Expectations are managed	✓ Feedback loop to citizens on how data is used	✓ Time needed for change & misconnection resolution
Data management plan procedures are established	✓ Data custodian	✓ National data infrastructure

Identified pathways of change and causal assumptions were documented, along with a risk analysis to check the validity of each assumption, to identify which assumptions are most critical to monitor and to devise mitigation measures in case an assumption is wrong (see Table 16 for example from the Outfall Safari case study).

Table 16 Example of prioritised assumptions and mititgation measures from Outfall Safari

Assumptions	Likelihood of assumption being invalid (low/high)	Level of consequence of assumption being wrong (mild/serious consequences)	Mitigation measure
Water companies are interested in Outfall Safari and will want to be involved.	High	Serious	Ensure water companies have a clear brief that outlines the aims, objectives and benefits of project. Also outline their role
Local stakeholders are interested in the work and benefits.	High	Serious	Ensure local stakeholders have a clear brief that outlines the aims, objectives and benefits of project. Also outline their role

Assumptions	Likelihood of assumption being invalid (low/high)	Level of consequence of assumption being wrong (mild/serious consequences)	Mitigation measure
Citizens recognise the right time to conduct the surveys (e.g., surveys should not be completed straight after a storm event)	Mild	Low	Ensure citizens know the appropriate time of year to conduct survey; requires training and communication

5.3.6 Validating the ToC with local stakeholders

In order to validate the ToC with local stakeholders, one or more workshops were (or are being) designed and organized in each MICS case study. The design of the workshops enabled the participants to discuss, identify and validate the building blocks and pathways of change that help complete the ToC per case study.

Depending on the local circumstances and the restrictions applying due to the COVID-19 pandemic, these workshops were either held online or face to face. In case of the online workshops, Miro.com was used as an interactive tool to allow participants validate different elements of the ToC. In case of face-to-face workshops, post-it notes and printed material were used to document ideas and feedback. In both settings, participants worked in small groups and discussed different elements of the ToC including, long-term impacts, short-term impacts, causal relationships. The ToC was validated with the local stakeholders during the workshop, displaying the ToC and using the following instructions:

Working as a group in MIRO
Look at the impacts (both the long-term and short-term) identified in the draft impact journey
Consider the following:

- *What should be adjusted/changed?*
- *What is missing?*
- *Anything not applicable/relevant (delete)?*

The resulting feedback was analysed by the MICS team and the ToC adjusted, as needed.

5.4 Step 3 - Planning, Monitoring, Evaluation, and Learning (PMEL)

Main objective of this stage:

Develop a practical and flexible plan for motoring and evaluation monitoring and evaluation of impacts of the citizen science initiatives, based on the mapped ToC and the indicators in the MICS conceptual framework.

Details:

The third step in application of the MICS conceptual framework consists of developing a plan for monitoring and evaluation of impacts of the citizen science initiatives in the case studies. The plan for monitoring and evaluation of the impacts of MICS case studies should allow for monitoring the effects of the strategies and actions taken in the case on its outcomes and impacts. Monitoring of all outcomes is usually not feasible within the available timeframe and resources. Therefore, choices need to be made about which outcomes will be monitored.

In the application of the MICS conceptual framework, these choices were made in collaboration with local stakeholders during dedicated workshops. During the workshops, the stakeholders voted to identify which short-term and long-term changes (outcomes and impacts) are most important to monitor. They also discussed possible indicators of change for each outcome and impact, including practical aspects of monitoring the changes such as by whom, when, and how often the selected indicators should be monitored. The insights gathered from the stakeholder workshops were further analysed and consolidated by the members of the MICS team to set up a monitoring and evaluation plan per case study. These tailored monitoring schemes provide the core intersection with the identified indicators in the MICS conceptual framework. Table 17 presents the generic plan for monitoring and evaluation of impacts of the MICS case studies. Annex 11 presents the draft impact monitoring scheme of the Outfall Safari case study in the UK.

Table 17 Generic structure of impact monitoring scheme

Outcomes / impacts to be monitored	Indicators	Description of indicator	Method type(s)	Frequency of measurement	Responsibility	Costs
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

Moreover, the actually identified outcomes and impacts in all five MICS case studies have been clustered by domain (see

Table 18 and

Table 19). These clusters were labelled with an overarching agreegrate indicator title in order to translate the case-specific outcomes and impacts to more generic phenomena and thus enable easier identification of suitable indicators in the MICS conceptual framework.

The updated version of this deliverable will present the complete monitoring schemes for all five MICS case studies.

Legend

Creek Rakos
Marzenego River
Carashuat Wetland
Outfall Safari
Riverfly

Table 18 Overview of outcomes (short-term impacts) in the MICS case studies

Domain	Title in Case Studies ToCs	General Indicator title
Environment	Sites for restoration identified	Location of environmental issues identified
	Locations of misconnections investigated	
	Risk areas, sites requiring protection & other and issues quickly identified	
	Pollution source identified and remedied	
	Outfalls prioritized	Environmental problems prioritized
	Remediation of polluting outfalls	
	Opportunistic pollution events reduced	
	Application of Outfall Safari method in other urban areas	Improved environmental state because of broader uptake of CS methods
	Application of Extended Riverfly methodology by other Riverfly groups	
Society	Improved communication and information exchange among stakeholders	Improved communication and information exchange among stakeholders
	Increased wider public awareness of the environment	Increased wider public awareness, understanding, knowledge of the environment
	Learning: Better understanding of the environment	
	Increased citizen awareness of riparian vegetation, water and NBS	
	Enhanced citizen scientist knowledge	
	Enhanced citizen scientist knowledge	
	Increased acceptance and support for restoration	Increased acceptance and support for environmental solutions (e.g. restoration)
	Increased bargaining power based on the collective experience	Increased bargaining power based on the collective experience
	Uptake of CS activities by more schools	Uptake of CS activities by more stakeholders (e.g. schools)
	Increased collaboration of local stakeholders with EA	Increased collaboration of local stakeholders
	Improved cooperation between stakeholders	
	Improved relationships among stakeholders	Improved relationships among stakeholders
	Improved relationships among stakeholders	
	Stronger community feeling / sense of place	Stronger community feeling / sense of place
	Increased active involvement - cascade effect	Increased active involvement - cascade effect

	Increased active involvement - cascade effect	
	Improved mental and physical health of volunteers	Improved mental and physical health of volunteers
	Improved mental and physical health of volunteers	
	Upskilling	Upskilling
Governance	Restoration planned; commitment (money & resources) from decision makers	Change in management plans, policies, regulations
	Contribution to management plans/policy:	
	Baseline data used to wetland mgt & exploitation plan as part of Delta plan	
	Targets for mitigating polluting outfalls met	Management or policy target met
	Political pressure on local MPs, etc. and water companies and EA (by citizen scientists and wider public)	Change in power dynamics via putting pressure on policy makers and decision makers
	Resources prioritized to address environmental issue	Resources prioritized to address environmental issue
	Reduced cost of monitoring for regional environmental agency	Reduced costs of managing natural resources
Economy	Demand side growth:	Demand increased
	Increased number of eco-tourists / visitors to wetlands	
	Job creation, e.g. tour guides, hotels and tourism industry + support industry	Jobs created
Science & Technology	Learning: expertise in CS-enhanced scientific methodology	Improved CS capacity of scientists
	Shared understanding of how to run effective citizen science activities	
	Improved knowledge regarding additional river stressors	Improved scientific knowledge about the environment
	Improved data coverage (Lincolnshire)	Improved data coverage

Table 19 Overview of impacts (long-term impacts) in the MICS case studies

Domain	Title in Case Studies ToCs	General Indicator title
Environment	Restoration implemented	Improved status of the environment
	Improved ecosystem/biophysical environment (water quality, biodiversity) of the Creek	
	Improved wetlands (NBSs), river quality and riparian vegetation	
	Improved ecosystem/biophysical environment [water quality, biodiversity, stable slopes] of the wetland	
	Improved river water quality and habitat	
	Improved river water quality and habitat (including recreational fisheries)	
Society	Improved environmental stewardship	Improved environmental stewardship
	Citizens have holistic understanding of freshwater ecosystems	Improved public awareness and knowledge of the environment
	Wider public awareness / changing attitudes of polluting outfalls	
	Increased recognition of the scientific role of secondary schools in environmental management	Enhanced scientific citizenship
	Improved living standards	Improved quality of life
	Improved volunteer health	
	Community building	Improved community building
	Community building	
Governance	Increased capacity (statutory agencies) for observing the Creek and its surroundings	Increased knowledge & capacity of public authorities
	Authorities have better understanding of the natural system (critical issues identified)	
	Improved decision making – local municipality, Budapest municipality, water authority	Improved environmental decision making
	Improved decision-making regarding polluting outfalls	
	Improved decision making [Danube Delta Biosphere Reserve Authority, local authorities]	
	Improved decision-making regarding river management	
	Improved flood risk management	Change in management plans, policies, regulations
	Increased uptake of NBS to tackle environ issues	
	Improved Policies / Legislation	
	Changed policy priorities	
	Improved conservation (additional sites with protected status)	

	Improved conservation: Support for sites requiring protected status	
Economy	Improved / diversified local economy [tourism]	Diversification and improvement of local economy
	Business Creation	
Science & Technology	Improved scientific knowledge	Improved scientific knowledge
	Increased institutional knowledge in how to run effective citizen science project	Improved CS capacity of institutions

6 Conclusions & next steps

This report has presented the draft MICS conceptual framework which constitutes the overarching structure within which novel and appropriate impact assessment methods have been provided for citizen science projects and which will inform the MICS online platform in WP3. The draft framework has been tested in the MICS case studies. The guidance provided for applying the conceptual framework can used for piloting by the wider citizen science community. The updated, final version of the MICS conceptual framework will be submitted by December 2021.

The extent to which the progress to date aligns with the principles guiding the work of developing the MICS conceptual framework is summarised in Table 20. This shows that, to a large extent, the principles have been fully applied already in the current implementation (conceptual and as used in the MICS case studies). Notable exceptions are the links to the SDGs; guidance on impact assessment methods for a given outcome or impact from a range of options; indication of confidence levels depending on the selection of indicator and associated methods and evidence base; and arrangements for enabling the collective and cumulative enhancement of the framework over time. The latter in particular can be implemented on the MICS platform and/or the EU.citizenscience platform. A tiered level of indicators (similar to the SDG Tier 1-2 and 3 system of indicators[5]) may be used to indicate the maturity level or peer review status of new indicators that are under review by the MICS consortium. A similar system may need to be set up and maintained for curation of the MICS framework beyond the lifetime of the project and will require explicit attention during the remaining project life time.

The results of this report will feed into the MICS following activities:

WP2 Methods for measuring citizen science impact

- Wider piloting by the citizen science community and peer review of the framework (Task 2.6 Development and maintenance of the conceptual framework)

WP3 Toolboxes for methods application, information visualisation and

- Inform the MICS online platform (Task 3.4 Development and maintenance of the platform), by drawing on the generic indicators identified in the literature as well as the specific ones identified in the case studies.
- This will contribute to D3.5 Participatory, adaptive, personalised, information-delivery web platform, period-2 prototype (P2P)

WP4 Test site development and tool validation

- Continued testing of the framework by the MICS case studies (Task 4.4 Application of the citizen-science impact methodology), the results of which will be captured in D4.5 Comprehensive evaluation report

Across these activities, the feasibility of diverse and comprehensive data collection methods and the implications for data management will require continued attention. Similarly, the curation of the MICS conceptual framework during and after the project life time will need careful consideration.

[5] Tier 1 and 2: indicator is conceptually clear and has an internationally established methodology vs. Tier 3: no internationally established methodology or standards are yet available for the indicator, but methodology/standards are being (or will be) developed or tested.

Table 20 Overview of current implementation against guiding principles for the MICS conceptual framework

Key aspect	Description	Guiding principle for MICS conceptual framework	Current implementation
Purpose of citizen-science impact assessment	The reasons for impact assessment of citizen-science projects differ from 'mere' impact reporting to learning for improved (future) implementation and even ex ante IA to substantiate proposal and grant applications.	The MICS conceptual framework needs to be able to accommodate a range of reasons, purposes and timing of undertaking IA of citizen-science projects. This requires the provision of process as well as results-related indicators, benchmarks and feedback on the extent to which and the ways in which envisaged results are and can be achieved, feeding into the adaptive management of citizen-science projects.	✓ The approach can be used for a range of reasons and purposes ✓ The indicators in all 5 domains include process as well as results-related indicators and as such can inform adaptive management of ongoing citizen science projects as well as progress and end of project reporting.
Non-linear impact journeys rather than impact silos	The limitations of linear conceptualisations of the logic framework are increasingly evident, especially in the field of citizen-science. Moreover, evidence from citizen-science impact assessments has shown that impact journeys are not linear within domains but that they 'zigzag' *across* domains.	The MICS conceptual framework needs to provide sufficient flexibility in the selection of relevant impact domains and respective intermediary outcomes. Users need to be able to *plan and trace impact pathways in and across the MICS domains (*society, economy, environment, governance, and science). For this, sound distinctions between outputs, outcomes and impacts in each domain are essential; moreover, causal relations not only between intermediary outcomes and impacts within a given domain but also *between outcomes in different* domains must be identifiable and traceable. Similarly, it needs to be possible to select and adjust over time which SDGs the citizen-science project intends and actually contributes to	✓ One or more of the five impact domains can be selected and relevant outcomes can be selected, these are not prescribed and additional ones added, as applicable. ✓ Impact pathways are traceable via the (visualised) ToC [impact journeys] ✓ Clear distinctions between outputs, outcomes and impacts per domain applied; generic activities and outputs already identified across the MICS case studies ✓ Causal relations between outcomes/impacts in different domains are identifiable and traceable in the ToC • Links to SDGs: not yet implemented
IA data collection methods & information sources	Sound IA of citizen-science projects involves a range of data collection methods and ideally includes not only participants but relevant stakeholders and beneficiaries who can provide evidence of (evolving) impacts.	The way in which users provide evidence needs to allow and guide them within a wide range of suitable IA data collection methods and stakeholders to be involved, but without being prescriptive. Moreover, data collection for impact assessment of citizen-science activities under the MICS conceptual framework should allow its users to 'practice what we preach' by involving citizen scientists in the collection of evidence about emerging impacts, entailing measurement not only against 'scientific' indicators but also against community-defined success.	✓ The shortlist of vetted indicators provides information about data collection methods as suggested by the respective authors. ✓ Measurement of community-defined success is inherent to the implemented approach and has been applied in all five case studies already. • Guidance on suitable IA data collection methods: not yet implemented

Key aspect	Description	Guiding principle for MICS conceptual framework	Current implementation
	Citizen-science projects have different resources (financial, time, qualified staff) at their disposal for their IA efforts which affect the extent of their IA efforts and hence the type and range of evidence that they can provide.	The MICS conceptual framework should provide sufficient and appropriate guidance, instructions as well as links to relevant resources to support IA data collection efforts of CS projects.	• Guidance on suitable IA data collection methods without being prescriptive: not yet implemented
Relative vs absolute impact	The limitations of sticking to absolute and fixed measures of impact (typically quantified) are becoming increasingly evident, including in the field of citizen science. Sound IA needs to measure impact to relative to the context and the goals and objectives of citizen science projects.	The MICS conceptual framework needs to provide the means to enter and measure progress against project-specific objectives and taking contextual realities into account (geographical, socio-economic setting, resources available (time, financial, staff, etc.)).	✓ Measuring progress against project-specific objectives and taking context into account is inherent in the MICS conceptual framework. ✓ Most, if not all, indicators in the framework provide the means to measure related rather absolute impact, using a mix of qualitative and quantitative data.
Comparison of IA results across citizen-science projects	The diversity of CS projects in terms of thematic issues addressed, stakeholders involved, extent and type of IA undertaken, etc., can make it challenging to compare results across projects.	The MICS conceptual can provide room for comparability of IA results that are based on different methods and information sources by using consistent overarching categories of definitions but distinguishing *confidence levels* (or similar, e.g. via a colour scheme) that stem from and indicate the (limited) range of underlying data sources. This can serve to generate individual as well as aggregate results.	• Indication of confidence levels in selected indicator, method and provided evidence: not yet implemented
Cumulative enhancement of the framework over time	The collective advancement of impact assessment theory and practice in the field of citizen science relies on reflection and cumulative additions, based on insights across projects and methods.	In order to remain relevant over time and serve the CS IA community, the MICS conceptual needs to be built on collective and cumulatively evolving intelligence, based on additional user inputs and definitions as well as more structured reflection and quality control (peer review) to check whether appropriate items/definitions/methods are being used.	• Set up for collective and cumulative enhancement of the framework over time: not yet implemented

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Annex 1 Environmental Attitudes Inventory (Milfont & Duckitt, 2010)

Method

This questionnaire can be shared with participants either online or physically. Each scale reflects a different dimension of environmental attitudes (as indicated below).

Milfont and Duckitt (2010) present the mean scores for each dimension in their study, providing a base line for the future assessment of environmental attitudes with this scale: Enjoyment of Nature (6.11); Conservation Policies (6.02); Environmental Activism (5.17); Anthropocentric Concern (3,51); Confidence in Science (3.63); Environmental Fragility (5.46); Altering Nature (3.55); Personal Conservation (5.82); Dominance over Nature (2.54); Utilization of Nature (2.67); Ecocentric Concern (6.13); and Population Concern (4.12).

Higher scores (after accounting for the reverse coded items) suggests a more pro-environmental attitude.

Materials

Question responses range from: 1 (strongly disagree) to 7 (strongly agree).

Scale 01. Enjoyment of nature

01. I am NOT the kind of person who loves spending time in wild, untamed wilderness areas. (R)
02. I really like going on trips into the countryside, for example to forests or fields.*,†
03. I find it very boring being out in wilderness areas. (R)*
04. Sometimes when I am unhappy, I find comfort in nature.
05. Being out in nature is a great stress reducer for me.*
06. I would rather spend my weekend in the city than in wilderness areas. (R)
07. I enjoy spending time in natural settings just for the sake of being out in nature.
08. I have a sense of well-being in the silence of nature.*
09. I find it more interesting in a shopping mall than out in the forest looking at trees and birds. (R)*
10. I think spending time in nature is boring. (R)*,†

Scale 02. Support for interventionist conservation policies

01. Industry should be required to use recycled materials even when this costs more than making the same products from new raw materials.
02. Governments should control the rate at which raw materials are used to ensure that they last as long as possible.*,†
03. Controls should be placed on industry to protect the environment from pollution, even if it means things will cost more.*
04. People in developed societies are going to have to adopt a more conserving life-style in the future.*
05. The government should give generous financial support to research related to the development of alternative energy sources, such as solar energy.
06. I don't think people in developed societies are going to have to adopt a more conserving life-style in the future. (R)*

07. Industries should be able to use raw materials rather than recycled ones if this leads to lower prices and costs, even if it means the raw materials will eventually be used up. (R)*
08. It is wrong for governments to try and compel business and industry to put conservation before producing goods in the most efficient and cost effective manner. (R)
09. I am completely opposed to measures that would force industry to use recycled materials if this would make products more expensive. (R)
10. I am opposed to governments controlling and regulating the way raw materials are used in order to try and make them last longer. (R)*,†

Scale 03. Environmental movement activism

01. If I ever get extra income I will donate some money to an environmental organization.
02. I would like to join and actively participate in an environmentalist group.*,†
03. I don't think I would help to raise funds for environmental protection. (R)*
04. I would NOT get involved in an environmentalist organization. (R)*,†
05. Environmental protection costs a lot of money. I am prepared to help out in a fund-raising effort.*
06. I would not want to donate money to support an environmentalist cause. (R)*
07. I would NOT go out of my way to help recycling campaigns. (R)
08. I often try to persuade others that the environment is important.
09. I would like to support an environmental organization.*
10. I would never try to persuade others that environmental protection is important. (R)

Scale 04. Conservation motivated by anthropocentric concern

01. One of the best things about recycling is that it saves money.
02. The worst thing about the loss of the rain forest is that it will restrict the development of new medicines.
03. One of the most important reasons to keep lakes and rivers clean is so that people have a place to enjoy water sports.*,†
04. Nature is important because of what it can contribute to the pleasure and welfare of humans.*
05. The thing that concerns me most about deforestation is that there will not be enough lumber for future generations.*
06. We should protect the environment for the well-being of plants and animals rather than for the welfare of humans. (R)
07. Human happiness and human reproduction are less important than a healthy planet. (R)
08. Conservation is important even if it lowers peoples' standard of living. (R)*
09. We need to keep rivers and lakes clean in order to protect the environment, and NOT as places for people to enjoy water sports. (R)*,†
10. We should protect the environment even if it means peoples' welfare will suffer.(R)*

Scale 05. Confidence in science and technology

01. Most environmental problems can be solved by applying more and better technology.
02. Science and technology will eventually solve our problems with pollution, overpopulation, and diminishing resources.*
03. Science and technology do as much environmental harm as good. (R)
04. Modern science will NOT be able to solve our environmental problems. (R)*,†

05. We cannot keep counting on science and technology to solve our environmental problems. (R)*
06. Humans will eventually learn how to solve all environmental problems.*
07. The belief that advances in science and technology can solve our environmental problems is completely wrong and misguided. (R)*
08. Humans will eventually learn enough about how nature works to be able to control it.
09. Science and technology cannot solve the grave threats to our environment. (R)
10. Modern science will solve our environmental problems.*,†

Scale 06. Environmental threat

01. If things continue on their present course, we will soon experience a major ecological catastrophe.*
02. The earth is like a spaceship with very limited room and resources.
03. The balance of nature is very delicate and easily upset.
04. When humans interfere with nature it often produces disastrous consequences.*
05. Humans are severely abusing the environment.*,†
06. The idea that we will experience a major ecological catastrophe if things continue on their present course is misguided nonsense. (R)
07. I cannot see any real environmental problems being created by rapid economic growth. It only creates benefits. (R)
08. The idea that the balance of nature is terribly delicate and easily upset is much too pessimistic. (R)*
09. I do not believe that the environment has been severely abused by humans. (R)*,†
10. People who say that the unrelenting exploitation of nature has driven us to the brink of ecological collapse are wrong. (R)*

Scale 07. Altering nature

01. Grass and weeds growing between paving stones may be untidy but are natural and should be left alone. (R)
02. The idea that natural areas should be maintained exactly as they are is silly, wasteful, and wrong.
03. I'd prefer a garden that is wild and natural to a well-groomed and ordered one. (R)*,†
04. Human beings should not tamper with nature even when nature is uncomfortable and inconvenient for us. (R)*
05. Turning new unused land over to cultivation and agricultural development should be stopped. R)*
06. I'd much prefer a garden that is well groomed and ordered to a wild and natural one.*,†
07. When nature is uncomfortable and inconvenient for humans we have every right to change and remake it to suit ourselves.*
08. Turning new unused land over to cultivation and agricultural development is positive and should be supported.
09. Grass and weeds growing between pavement stones really looks untidy.*
10. I oppose any removal of wilderness areas no matter how economically beneficial their development may be. (R)

Scale 08. Personal conservation behaviour

01. I could not be bothered to save water or other natural resources.(R)*
02. I make sure that during the winter the heating system in my room is not switched on too high.
03. In my daily life I'm just not interested in trying to conserve water and/or power. (R)*
04. Whenever possible, I take a short shower in order to conserve water.
05. I always switch the light off when I don't need it on any more.*
06. I drive whenever it suits me, even if it does pollute the atmosphere. (R)
07. In my daily life I try to find ways to conserve water or power.*
08. I am NOT the kind of person who makes efforts to conserve natural resources. (R)*,†
09. Whenever possible, I try to save natural resources.*,†
10. Even if public transportation was more efficient than it is, I would prefer to drive my car. (R)

Scale 09. Human dominance over nature

01. Humans were meant to rule over the rest of nature.*
02. Human beings were created or evolved to dominate the rest of nature.*,†
03. Plants and animals have as much right as humans to exist. (R)*
04. Plants and animals exist primarily to be used by humans.*
05. Humans are as much a part of the ecosystem as other animals. (R)
06. Humans are no more important in nature than other living things. (R)
07. Nature exists primarily for human use.
08. Nature in all its forms and manifestations should be controlled by humans.
09. I DO NOT believe humans were created or evolved to dominate the rest of nature.(R)*,†
10. Humans are no more important than any other species. (R)*

Scale 10. Human utilization of nature

01. It is all right for humans to use nature as a resource for economic purposes.
02. Protecting peoples' jobs is more important than protecting the environment.*,†
03. Humans do NOT have the right to damage the environment just to get greater economic growth. (R)*
04. People have been giving far too little attention to how human progress has been damaging the environment. (R)
05. Protecting the environment is more important than protecting economic growth. (R)*
06. We should no longer use nature as a resource for economic purposes. (R)
07. Protecting the environment is more important than protecting peoples' jobs. (R)*,†
08. In order to protect the environment, we need economic growth.
09. The question of the environment is secondary to economic growth.*
10. The benefits of modern consumer products are more important than the pollution that results from their production and use.*

Scale 11. Ecocentric concern

01. The idea that nature is valuable for its own sake is naïve and wrong. (R)*
02. It makes me sad to see natural environments destroyed.
03. Nature is valuable for its own sake.*
04. One of the worst things about overpopulation is that many natural areas are getting destroyed.

05. I do not believe protecting the environment is an important issue. (R)*
06. Despite our special abilities humans are still subject to the laws of nature.*
07. It makes me sad to see forests cleared for agriculture.*,†
08. It does NOT make me sad to see natural environments destroyed. (R)*,†
09. I do not believe nature is valuable for its own sake. (R)
10. I don't get upset at the idea of forests being cleared for agriculture. (R)

Scale 12. Support for population growth policies

01. We should strive for the goal of "zero population growth".
02. The idea that we should control the population growth is wrong. (R)
03. Families should be encouraged to limit themselves to two children or less.*,†
04. A married couple should have as many children as they wish, as long as they can adequately provide for them. (R)*,†
05. Our government should educate people concerning the importance of having two children or less.*
06. We should never put limits on the number of children a couple can have. (R)*
07. People who say overpopulation is a problem are completely incorrect. (R)
08. The world would be better off if the population stopped growing.
09. We would be better off if we dramatically reduced the number of people on the Earth.*
10. The government has no right to require married couples to limit the number of children they can have. (R)*

Note. R = reversed coded items.

* The 72 balanced items selected for the short version of the EAI (i.e., EAI-S).

† The 24 balanced items selected for the brief version of the EAI (i.e., EAI-24).

Annex 2 Measuring environmental motives (Schultz, 2001)

Methods

These questions can be shared with participants digitally or physically. The items in the questionnaire reflect three dimensions of environmental attitudes: biospheric (questions 1-4), egoistic (questions 5-8) and altruistic (questions 9-12).

Schultz (2001) presented the mean scores for each sub-scale in his study, providing a base line for the future assessment of environmental attitudes with this scale. Average scores for the sub-scales were: biospheric (5.46); egoistic (5-48); and altruistic concerns (5.84).

Materials

People around the world are generally concerned about environmental problems because of the consequences that result from harming nature. However, people differ in the consequences that concern them the most. Please rate each of the following items from 1 (not important) to 7 (supreme importance) in response to the question:

I am concerned about environmental problems because of the consequences for:

1. Plants
2. Me
3. People in my country*
4. Marine life
5. My lifestyle
6. All people
7. Birds
8. My health
9. Children
10. Animals
11. My future
12. My children**

*An alternative wording is 'People in the community'

**An alternative wording is 'Future generations.'

Annex 3 General Ecological Behavior Scale (Kaiser, 2020)

Method

This questionnaire can be completed by participants either online or physically.

In an earlier version of the scale, Kaiser and Wilson (2004), suggested that during analysis of the results, the responses to the first 32 items be recoded into an alternative format by combining never, seldom, and occasionally as indicators of environmental behaviours. Often and always should then be combined to indicate pro-environmental behaviours.

Materials

For the following 32 behaviors, please indicate how often you perform them. Questions are answered ‘never’, ‘seldom’, ‘occasionally’, ‘often’, ‘very often’, or ‘NA’. Choose “Not applicable” (NA) if you are unable to give an answer.

1 I ride a bicycle or take public transportation to work or school.
2 I buy meat and produce with eco-labels.
3 I buy beverages in cans.
4 I use an oven cleaning spray to clean my oven.
5 I wait until I have a full load before doing my laundry.
6 I drive my car in or into the city.
7 In the winter, I air rooms while keeping on the heat and leaving the windows open, simultaneously.
8 I wash dirty clothes without prewashing.
9 I drive on freeways at speeds under 100kph (= 62.5 mph).
10 If I am offered a plastic bag in a store, I take it.
11 In nearby areas (around 30 kilometers; around 20 miles), I use public transportation or ride a bike.
12 I collect and recycle used paper.
13 I bring empty bottles to a recycling bin.
14 I have pointed out unecological behavior to someone.
15 I contribute financially to environmental organizations.
16 I buy beverages and other liquids in returnable bottles.
17 I buy bleached or colored toilet paper.
18 I buy convenience foods.
19 I buy products in refillable packages.
20 I buy domestically grown wooden furniture.
21 I boycott companies with an unecological background.
22 I buy seasonal produce.
23 I use a clothes dryer.
24 I read about environmental issues.
25 I talk with friends about environmental pollution, climate change, and/or energy consumption.
26 For longer journeys (more than 6 hours of travel time by car), I take an airplane.
27 I keep the engine running while waiting in front of a railroad crossing or in a traffic jam.
28 At red traffic lights, I keep the engine running.
29 I kill insects with a chemical insecticide.
30 In winter, I turn down the heat when I leave my apartment for more than 4 hours.

31 I drive to where I want to start my hikes.
32 I shower (rather than to take a bath)

For the following 18 behaviors, please indicate whether you perform them or not. Choose the answer that fits your situation closest. Again, choose "Not applicable" (NA) if you are unable to give an answer

1 I reuse my shopping bags.
2 In the winter, I keep the heat on so that I do not have to wear a sweater.
3 I use fabric softener with my laundry.
4 I put dead batteries in the garbage.
5 After meals, I dispose of leftovers in the toilet.
6 I use a chemical air freshener in my bathroom.
7 I am a member of an environmental organization.
8 In hotels, I have the towels changed daily.
9 I own an energy efficient dishwasher (efficiency class A+ or better).
10 After a picnic, I leave the place as clean as it was originally.
11 I own solar panels.
12 I have looked into the pros and cons having a private source of solar power.
13 I have a contract for renewable energy with my energy provider.
14 I refrain from owning a car.
15 I am a member of a carpool.
16 I drive in such a way as to keep my fuel consumption as low as possible.
17 I own a fuel-efficient automobile (less than 6 liters per 100 kilometer).
18 I am a vegetarian.

Annex 4 Environmental knowledge measurement scale (Braun & Dierkis, 2019)

Method

This questionnaire can be completed by participants either online or physically. Correct answers to each question are highlighted below. Note that several questions have more than one correct answer, this should be made clear to participants in advance.

Materials

System knowledge	Deforestation causes…	A change in the amount of rainfall
		Destruction of habitats
		A dryer and hotter climate
		More fertile ground
	Which of the following is the reason for the greenhouse effect?	The proceeding destruction of the ozone layer
		Increased vegetation on earth
		Increased amount of carbon dioxide in the atmosphere
		The melting of the polar ice caps
	Which of these products do not contain palm oil?	Paper
		Soap
		Chocolate
		Cosmetics
	Which are coniferous trees?	Beech tree
		Douglas fir
		Palm tree
		Spruce
Action-related knowledge	What can contribute to the conservation of plants and animals?	Feeding birds in the park with bread
		Buying sustainable products (e.g. wood with the FSC seal)
		Buying products of endangered species (e.g. ivory)
		Planting native vegetation in the yard
	You can minimise energy consumption by…	Wasting less warm water
		Using the airconditioning on a high level
		Turning off the lights when leaving a room
		Leaving electric devices on standby mode
	What belongs in a sustainable shopping basket?	Seasonal and regional products
		Convenience food
		Organic food
		Imported goods

	How can you contribute to a healthy environment?	Washing your clothes less often
		Using public transport
		Using plastic cups
		Eating more meat
Effectiveness Knowledge	How much water can be saved by taking a shower instead of a bath?	Up to 500 liters
		Up to 120 liters
		Up to 70 liters
		Up to 30 liters
	By using which kind of bottle do you damage the environment the most?	Single use glass bottles
		Reuseable glass bottles
		Single use plastic bottles
		Reusable plastic bottles
	By avoiding which food(s) can you save the most greenhouse gases?	Fruits and vegetables
		Meat
		Bread and rice
		Sweets
	How much electricity can be saved by using an energy-saving bulb instead of a conventional bulb?	Up to 10%
		Up to 20%
		Up to 50%
		Up to 80%

Annex 5 Assessment of Sustainability Knowledge (ASK) (Zwickle & Jones, 2018)

Method

This questionnaire can be completed by participants either online or physically. The answers marked in bold below are the correct answers.

When designing a study and analysing results, Zwickle & Jones (2018, p444) state that "The most logical and practical use is to evaluate the effectiveness of an educational program through either a pre and post-test, or by comparing a treatment group to a control". Therefore, to obtain a baseline when examining the effect of Citizen Science on environmental knowledge, participants should be tested before and after participation in the project (or a control group should be found).

Materials

1. What is the most common cause of pollution of streams and rivers?
    a. Dumping of garbage by cities
    b. Surface water running off yards, city streets, paved lots, and farm fields
    c. Litter near streams and rivers
    d. Waste dumped by factories
2. Ozone forms a protective layer in the earth's upper atmosphere. What does ozone protect us from?
    a. Acid rain
    b. Climate change
    c. Sudden changes in temperature
    d. Harmful UV rays
3. Which of the following is an example of sustainable forest management?
    a. Setting aside forests to be off limits to the public
    b. Never harvesting more than what the forest produces in new growth
    c. Producing lumber for nearby communities to build affordable housing
    d. Putting the local communities in charge of forest resources
4. Of the following, which would be considered living in the most environmentally sustainable way?
    a. Recycling all recyclable packaging
    b. Reducing consumption of all products
    c. Buying products labeled "eco" or "green"
    d. Buying the newest products available
5. Which of the following is the most commonly used definition of sustainable development?
    a. Creating a government welfare system that ensures universal access to education, health care, and social services
    b. Setting aside resources for preservation, never to be used
    c. Meeting the needs of the present without compromising the ability of future generations to meet their own needs
    d. Building a neighborhood that is both socio-demographically and economically diverse
6. Over the past 3 decades, what has happened to the difference between the wealth of the richest and poorest Americans?

a. The difference has increased
b. The difference has stayed about the same
c. The difference has decreased

7. Many economists argue that electricity prices in the U.S. are too low because…
    a. They do not reflect the costs of pollution from generating the electricity
    b. Too many suppliers go out of business
    c. Electric companies have a monopoly in their service area
    d. Consumers spend only a small part of their income on energy
8. Which of the following is the most commonly used definition of economic sustainability?
    a. Maximizing the share price of a company's stock
    b. Long term profitability
    c. When costs equal revenue
    d. Continually expanding market share
9. Which of the following countries passed the U.S. to become the largest emitter of the greenhouse gas carbon dioxide?
    a. China
    b. Sweden
    c. Brazil
    d. Japan
10. Which of the following is a leading cause of the depletion of fish stocks in the Atlantic Ocean?
    a. Fishermen seeking to maximize their catch
    b. Reduced fish fertility due to genetic hybridization
    c. Ocean pollution
    d. Global climate change
11. Which of the following is the best example of environmental justice?
    a. Urban citizens win a bill to have toxic wastes taken to rural communities
    b. The government dams a river, flooding Native American tribal lands to create hydro-power for large cities
    c. All stakeholders from an indigenous community are involved in setting a quota for the amount of wood they can take form a protected forest next to their village
    d. Multi-national corporations build factories in developing countries where environmental laws are less strict.
12. Put the following list in order of the activities with the largest environmental impact to those with the smallest environmental impact:
    A. Keeping a cell phone charger plugged into an electrical outlet for 12 h
    B. Producing one McDonald's quarter-pound hamburger
    C. Producing one McDonald's chicken sandwich
    D. Flying in a commercial airplane from Washington D.C. toChina

a. A, C, B, D
b. D, A, B, C
c. D, C, B, A
d. D, B, C, A

Annex 6 Society domain - reviewed indicators

Domain	Indicator Cluster	Indicator Name
Society	Individual level	Individual development
		Individual learning outcomes
		Environmental knowledge
		Sustainability Knowledge
		Individual learning outcomes
		Capacities (skills and competences)
		Value creation
		Individual learning
		Individual and societal impacts
		Participation and opportunities for learning
		Involvement and support
		Experience and efficacy
		Individual and societal outcomes
		Awareness, and knowledge of a resource
		Pro-environmental attitude
		Environmental motives
		Ecological Behavior
		Individual outcomes
		Transformative change
	Meso-level	Organizational outcomes
		Community building
		Dissemination and feedback
		Community engagement and participation
		Citizen-led research
		Participatory dynamics
	Societal level	Social and cultural characteristics of a resource
		Social inclusion
		Social capital
		Societal outcomes
		Societal outcomes related to human health
		Societal outcomes
		Societal knowledge exchange outcomes
		Societal impact
		Distribution of risks
		Environmental risk perception
	Science & society	Public engagement in science
		Civic action, identity and activism
		Public understanding of science
		Scientific knowledge and attitude change
	Access to Information	Information
	Capacity building & education	Capacity building
		Awareness and responsibility
		Environmental education and stewardship

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Individual development**
Description	Possibilities for individual development of participants
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	Science
Data collection method(s)	Not specified
Data collection item(s)	• What are the specific goals to be achieved by the participants? • What are the learning outcomes for the individuals? • Do individuals gain new knowledge, skills and competences? • Does the project contribute to a better understanding of science? • Does the project influence the values and attitudes of participants regarding science? • How much involvement and responsibility is offered to the participants? • Does the project foster ownership amongst participants? • Does the project contribute to personal change in behaviour? • Does the project raise motivation and self-esteem amongst participants? • Are participants motivated to continue the project or involve in similar activities? • In case of younger students, do they consider a scientific career?
Indicator building	• Knowledge, skills, competences • Attitudes and values • Behaviour and ownership • Motivation and engagement
Availability of data	low
Feasibility	Insufficient information to judge
Comments/caveats	
Source of indicator definition	Kieslinger et al. (2017; 2018)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Individual learning outcomes**
Description	Additional learning opportunities provided by the project
Domain	Society
Qual/Quantitative	Qualitative and quantitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Online repositories (e.g. Science Direct, Google Scholar, etc.); Social media analytics
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Output, outcome
Links with indicators in other domains	N/A
Data collection method(s)	Online surveys, interviews, and focus groups with projects participants, as well as usage statistics
Data collection item(s)	Not indicated and cannot be easily derived from the indicator building field
Indicator building	• Improved participant understanding of science content • Enhanced participant understanding of science process • Better participant attitudes toward science • Improved participant skills for conducting science • Increased participant interest in science as a career • other (case specific)
Availability of data	Medium-high
Feasibility	Insufficient information to judge
Comments/caveats	
Source of indicator definition	Bonney et al. (2009a&b)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Environmental knowledge**
Description	One's understanding of environmental processes and trends, and the influence of various factors on the planet
Domain	Society
Qual/Quantitative	Quantitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Context, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Questionnaire shared with participants in CS projects Multiple choice questions (some questions have more than one correct answer)
Data collection item(s)	A questionnaire- all items can be found here in the Appendix (Table 4) (Braun & Dierkes, 2017) - too elaborate to add here: https://link.springer.com/article/10.1007/s11165-017-9658-7
Indicator building	Made up of three dimensions of environmental knowledge: • Action-related • System • Effectiveness
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Braun & Dierkis (2019)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Sustainability Knowledge**
Description	One's understanding of the impact of human living on the environment, the economy and wider society, and specifically actions that can be taken to ensure that these three concept are not overtaxed
Domain	Society
Qual/Quantitative	Quantitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Context, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Multiple choice questionnaire shared with participants in CS projects
Data collection item(s)	A questionnaire - all items can be found here in Table 1 (Zwickle & Jones, 2018) - too elaborate to add here: https://www.researchgate.net/profile/Adam-Zwickle/publication/320674427_Sustainability_Knowledge_and_Attitudes-Assessing_Latent_Constructs/links/5a0f0324aca27299750744ab/Sustainability-Knowledge-and-Attitudes-Assessing-Latent-Constructs.pdf
Indicator building	Made up of three domains of sustainability knowledge: • Environmental • Economic • Social Number of correct answers indicates level of knowledge
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Zwickle & Jones (2018)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Individual learning outcomes**
Description	Change in learning that includes cognitive outcomes (the things people know), affective outcomes (how people feel), and behavioural outcomes (what people do)
Domain	Society
Qual/Quantitative	Qualitative and quantitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Secondary: (Publicly available) Project documentations (reports, information on websites, publications etc.)
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, input, process, output, outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Surveys of citizen science practitioners; Professional critique/expert review; Interviews with participants; Focus groups with participants or practitioners; Content analysis; Observations; Examine email/list serve messages; review of citizen science project websites
Data collection item(s)	Not indicated and cannot be easily derived from the indicator building field
Indicator building	• Change in Interest in Science & the Environment • Self-efficacy • Motivation • Knowledge of the Nature of Science • Skills of Science Inquiry • Behaviour & Stewardship
Availability of data	low
Feasibility	Insufficient information to judge
Comments/caveats	The concepts used for the indicator building are too complex to derive data collection items
Source of indicator definition	Phillips et al. (2012; 2014; 2018)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Capacities (skills and competences)**
Description	Specific skills and competences that individuals needs to participate in planning, decision making and governance processes
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Project partners, participants Secondary: Project documentations (reports, information on websites, publications etc.); Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, input, process, output, outcome, impact
Links with indicators in other domains	Governance
Data collection method(s)	Interviews with citizen observatory members and non-members stakeholders; review of project documentations (reports, log-books, etc.); analysis of the initiative tools (platforms, Apps, etc.); literature review
Data collection item(s)	8-10 questions are available for each topic in the indicator building - too elaborate to include here
Indicator building	Working together • Perception of community members of the influence they can have as a group • Frequency in which community actions are being organized • The frequency of formal collaborations between regulatory entities and stakeholder groups • Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically. (SDG 11.3.2) • Proportion of the population satisfied with their last experience of public services. (SDG 16.6.2) Creativity & flexibility • Experience of the community (incl. decision makers) in dealing with unexpected situations • Stringency of the regulations (under normal circumstances; when faced with a problem?) • Who can suggest new policy options? (only decision makers, also other professionals, all community members) • Individuals with low problem-solving skills in technology-rich environments Ability to learn • The uptake and reaction of community members to expert advice. • Past experiences and lessons community members are drawing on. • Participation in formal and/or non-formal education, by literacy proficiency level and educational attainment Internet savviness

	• Percentage of the community that has Internet access at home (- with average speed or more) • Percentage of the community that regularly exchanges images via the Internet • Percentage of the community that has Internet access at a friend's house • Fixed Internet broadband subscriptions per 100 inhabitants, by speed. (SDG 17.6.2)
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Value creation**
Description	Joint learning and knowledge co-construction that happened in the context of a participatory transnational project
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Participants, feedback forms Secondary: website statistics, social media
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Analysis of feedback forms after interactions (meetings), count of stakeholder participation, social media/website analytics
Data collection item(s)	Not specified, but can be derived from the following descriptions: • Indicators of immediate value include examples such as the company of like-minded people or doing something exciting • Indicators of potential value relate to what the community produced that had the potential to make a difference. • Indicators of applied value relate to the delivery of training materials in case studies and how the delivery of the professional development changed the knowledge, skills and understanding of the participants in the training. • Realized value relate to changes in practice that make a difference to what really matters to participants
Indicator building	**Immediate value** Indictors not specified (Collected via feedback forms) **Potential value** • Tools and documents • skills acquired by participants • New ways of learning **Applied value** • Change in knowledge of participants • Change in skills of participants • Change in understanding of participants **Realized value** Indictors not specified (collected through participant satisfaction surveys)
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	
Source of indicator definition	Guldberg et al. (2019)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Individual learning**
Description	Individually held values, beliefs and attitudes
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	No
Unit of measurement (observation)	Nominal
Unit of analysis	Individuals
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Participants' responses to a self-completed values questionnaire
Data collection item(s)	Items available, but operationalization is not included
Indicator building	• Beliefs • Values • Attitudes
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	
Source of indicator definition	Smajgl and Ward (2015)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Individual and societal impacts**
Description	Individual and societal benefits of citizen science in ecology and the environment
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Not specified
Source of data	Not specified
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	Environment
Data collection method(s)	Not specified
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Increased awareness of conservation and the environment • Creating next-generation conservation leaders and champions • Improved wellbeing and livelihoods • Enhanced capacity and empowerment of all stakeholders in conservation • Greater ownership; increased trust; change in tolerance and attitudes towards nature • Change in widening perspectives Developing and enhancing skills sets
Availability of data	Low
Feasibility	Insufficient information to judge
Comments/caveats	The items listed for the indicator building can be used to derive data collection items in simplistic ways. However, sound implementation would need to draw on scientific research in a number of relevant disciplines.
Source of indicator definition	Pocock et al. (2018)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Participation and opportunities for learning**
Description	Participation of volunteers and learning opportunities that the project provides for them
Domain	Society
Qual/Quantitative	Quantitative
Primary/Secondary data	Secondary data
Source of data	Raw classification files and project backups generated by the Zooniverse platform, as well as web analytics for individual projects, blogs, and Twitter feeds
Time-series	No
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Review of project documentation; web analytics for individual projects, blogs, and Twitter feeds
Data collection item(s)	• Number of volunteers • Project active period • Median volunteer active period • Median classifications per volunteer
Indicator building	• Project Appeal (Total number of volunteers who have contributed to the project divided by project active period squared) • Sustained Engagement (Median time interval (in weeks) between a registered user's first and last recorded classification divided by project active period squared) • Public Contribution (Median number of classifications per registered volunteer divided by project active period squared)
Availability of data	Low
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Cox et al. (2015)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Involvement and support**
Description	Possibilities for involvement in the project and support offered for participation
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Process
Links with indicators in other domains	N/A
Data collection method(s)	Not specified
Data collection item(s)	• Does the project have specific communication plans for target groups? • What engagement strategies does the project have (e.g. gamification)? • Are the options for participation and the degree of involvement diversified? • In which project phases are citizens involved? • Are citizens and scientists equal partners in the knowledge generation process? • Are support and training measures adapted to the different participant groups? • Are objectives and results clearly and transparently communicated? • How interactive is communication and collaboration between scientists and citizens organized? • Does the project involve organizations that provide of relations and communication structures with citizens?
Indicator building	• Target group alignment • Degree of intensity • Facilitation and communication • Collaboration and synergies
Availability of data	low
Feasibility	Insufficient information to judge
Comments/caveats	
Source of indicator definition	Kieslinger et al. (2017; 2018)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Experience and efficacy**
Description	Personal gains in terms of experiences gained and efficacy of the time spent for participation
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Publicly available data sources e.g. project deliverables and publications
Time-series	Not specified
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Citizen scientists' self-reports via surveys/questionnaires, focus groups, journaling, public data sources
Data collection item(s)	• How has participating in GROW Observatory inspired and energized you? • To what extent is the value created worth the time and effort you spent in this project?
Indicator building	Not specified
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	Unclear what personal specific personal gains are being measured.
Source of indicator definition	Woods et al. (2019)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Individual and societal outcomes**
Description	Citizen engagement and the effects of participation on participants
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Local and national audio-visual media and papers, and social media.
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Questionnaires filled by participants in the project, participant observations, informal research log books, observations, meeting minutes of the project team, media reports, and audio-visual material
Data collection item(s)	• Are there things you are doing differently or plan to do differently because of your participation in CurieuzeNeuzen? • Has your attitude changed regarding possible solutions to improve air quality (compared to before the start of CurieuzeNeuzen)?
Indicator building	• Change in engagement • Change in communication • Change in attitude and behaviour
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Van Brussel and Huyse (2018)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Awareness, and knowledge of a resource**
Description	Awareness of, and Knowledge about natural resources
Domain	Society
Qual/Quantitative	Qualitative
Primary/Secondary data	Secondary data
Source of data	(Publicly available) Project documentation (reports, information on websites, publications etc.)
Time-series	No
Unit of measurement (observation)	Ordinal (High, medium or low ranking)
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Review of case studies' documentations
Data collection item(s)	Not indicated and cannot be easily derived from the indicator building field
Indicator building	• Self-organization of a community or group around resource • Public awareness of resource • Knowledgeability of dedicated population • Ease of training or learning for monitoring
Availability of data	Low
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Chase and Levine (2016)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Pro-environmental attitude**
Description	The psychological tendency expressed by evaluating the natural environment with some degree of favour or disfavour
Domain	Society
Qual/Quantitative	Quantitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Context, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Questionnaire shared with participants in CS projects
Data collection item(s)	A questionnaire with scaled answers (range of 1 to 7, with 7 suggesting a more pro-environmental attitude) All items can be found here in Appendix 2 (Milfont & Duckitt, 2010) - too elaborate to add here: https://www.sciencedirect.com/science/article/pii/S0272494409000565
Indicator building	Scale 1. Enjoyment of nature Scale 2. Support for interventionist conservation policies Scale 3. Environmental movement activism Scale 4. Conservation motivated by anthropocentric concern Scale 5. Confidence in science and technology Scale 6. Environmental threat Scale 7. Altering nature Scale 8. Personal conservation behaviour Scale 9. Human dominance over nature Scale 10. Human utilization of nature Scale 11. Ecocentric concern Scale 12. Support for population growth policies
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	Pro-environmental attitude is measured by a 12 scale approach. Each scale reflects a different dimension of environmental attitudes. Data collection is done using a questionnaire consisting of several questions per scale. The questionnaire can be shared with participants either online or physically.
Source of indicator definition	Milfont and Duckitt (2010)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Environmental motives**
Description	The intensity of positive or negative affect about a particular environmental topic or a hierarchical attitude system that connects and organizes more specific attitudes about a range of environmental topics
Domain	Society
Qual/Quantitative	Quantitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Context, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Questionnaire shared with participants in CS projects
Data collection item(s)	A questionnaire with scaled answers [range of 1 (Not important at all) to 7 (supreme importance)] All items can be found here in Appendix 1 (Schultz, 2001) - too elaborate to add here: https://csusm-dspace.calstate.edu/bitstream/handle/10211.3/200707/Schultz200121.pdf?sequence=1
Indicator building	Three dimensions of environmental attitudes: • Biospheric • Egoistic • Altruistic Average scores for the sub-scales: biospheric (5.46); egoistic (5-48); and altruistic concerns (5.84).
Availability of data	Low
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Schultz (2001)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Ecological Behavior**
Description	Patterns or trends of actions that positively or negatively impact the environment
Domain	Society
Qual/Quantitative	Quantitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Context, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Questionnaire shared with participants in CS projects
Data collection item(s)	A questionnaire with scaled answers [range of 1 (never) to 5 (very often)], and Yes/No All items can be found here (Kaiser, 2020) - too elaborate to add here: https://psycharchives.org/handle/20.500.12034/3068
Indicator building	Unidimensional measure of general environmental behaviour (with assessment of a range of actions) Statements are answered with the frequency with which participants engage in the behaviour: ‘never’, ‘seldom’, ‘occasionally’, ‘often’, ‘very often’, or ‘NA’. Several of the statements are reverse coded. In analysis, ‘never’, ‘seldom’, and ‘occasionally’ should be combined as indicators of environmentally unfriendly behaviours. ‘Often’ and ‘always’ should then be combined to indicate pro-environmental behaviours
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Kaiser (2020)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Individual outcomes**
Description	Engaging people in transformational learning experiences that promote environmentally sustainable action
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project coordinator
Time-series	Yes, annual field reports
Unit of measurement (observation)	Ordinal (Low, medium, high)
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Review of project reports
Data collection item(s)	Not indicated and cannot be easily derived from the indicator building field
Indicator building	• Education: individuals engaged and developed increased capacity
Availability of data	Low
Feasibility	Insufficient information to judge
Comments/caveats	The concepts used for the indicator building are too complex to derive data collection items
Source of indicator definition	Chandler et al. (2017)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Transformative change**
Description	Individual learning, personal growth, sustainability, impact on policies, etc.
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, evaluation at four stages of a project - early stages, mid-project, end of the project, and post-project
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, process, outcomes
Links with indicators in other domains	Governance
Data collection method(s)	(online) self-evaluation questionnaires to be completed at four stages of a project - early evaluation, mid evaluation, end evaluation and post-project evaluation - designed to the profile of the respondents (i.e. civil society members, researchers, students, project managers)
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Knowledge and skills • Self-improvement • Collective capacity • Policy impact
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	The items listed for the indicator building can be used to derive data collection items in simplistic ways. However, sound implementation would need to draw on scientific research in a number of relevant disciplines.
Source of indicator definition	Gresle et al., (2019)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Public engagement in science**
Description	Degree to which participation in the project influences changes in behaviours related to participation in science-related activities, discussions, and policy making
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Process, outcome, impact
Links with indicators in other domains	Science
Data collection method(s)	Not specified
Data collection item(s)	As a result of new knowledge, interactions with other project members, or the negotiation: • are participants encouraged to evaluate individual science engagement behaviours against project experiences? • Do participants exhibit changes in behaviours regarding engagement in public science projects and processes?
Indicator building	Not specified
Availability of data	Low
Feasibility	Insufficient information to judge
Comments/caveats	The concepts used for the indicator building are too complex to derive data collection items
Source of indicator definition	Haywood and Besley (2013)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Civic action, identity and activism**
Description	Social identity as an active citizen
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Publicly available data sources e.g. project deliverables and publications
Time-series	Not specified
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Citizen scientists' self-reports via surveys/questionnaires, focus groups, journaling, public data sources
Data collection item(s)	• To what extent has participating in GROW Observatory contributed to your identity as someone who knows about, uses, and sometimes contributes to science? • Do you consider yourself as an active citizen?
Indicator building	Not specified
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Woods et al. (2019)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Public understanding of science**
Description	Change in public understanding of science because of participation in a project
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Publicly available data sources e.g. project deliverables and publications
Time-series	Review of project documentations; web analytics for individual projects and blogs
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Analysis of initiative forums and blogs; surveys & interviews with participants
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Change in Interest in science and nature • Self-efficacy for science and environmental action • Motivation for science and environmental action • Skills of science inquiry • Data interpretation skills • Knowledge of the nature of science • Environmental stewardship
Availability of data	Low
Feasibility	Insufficient information to judge
Comments/caveats	The items listed for the indicator building can be used to derive data collection items in simplistic ways. However, sound implementation would need to draw on scientific research in a number of relevant disciplines.
Source of indicator definition	Bonney et al. (2015)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Scientific knowledge and attitude change**
Description	Change in scientific knowledge, as well as attitude toward science and the environment
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Pre-test survey with a random control group of 400 members and a post-test survey with a non-random group of 300 participants Response choices 'agree' or 'disagree'. The value of agree=1 and disagree=0.
Data collection item(s)	**Attitude toward science scale items:** - Science and technology are making our lives healthier, easier, and more comfortable. - The benefits of science are greater than any harmful effects. - Science makes our way of life move too fast. - We depend too much of science and not enough on faith. **NEP/humans-with nature subscale items:** - Humans were created to rule over the rest of nature. - People have the right to modify the natural environment to suit their needs. - Plants and animals exist primarily to be used by people. - People need not to adapt to the natural environment because they can remake it to suit their needs. **Understanding of the scientific process items:** - When you hear or read the term 'scientific study' do you have (please check one): - a clear understanding of what it means - a general sense of what it means - little understanding of what it means - If you checked a) or b) for the previous question, please tell us in your own words what it means to study something scientifically: **Bird knowledge scale items:** - Most songbirds lay one egg per day during the breeding season. - Clutch size refers to the number of eggs a female bird can fit in her nest. - All birds line their nest with feathers. - Humans can handle nestlings with little fear of the nest being abandoned by the adult birds.

	- The age of a female bird can influence the number of eggs she lays. - Some birds need supplemental calcium to produce eggs. - Most cavity-nesting birds eat primarily seeds. - Cavity-nesting species that use nest boxes are safe from predators. - Some species of warblers use nest boxes. - Nest boxes should never be made of pressure-treated wood.
Indicator building	• Change in Scientific knowledge of community members • Understanding of community members about scientific processes • Attitude towards science • Attitude towards the environment
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Brossard et al. (2005)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Organizational outcomes**
Description	Enabling organizations and business to become more sustainable
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project coordinator
Time-series	Yes, annual field reports
Unit of measurement (observation)	Ordinal (Low, medium, high)
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Review of project reports
Data collection item(s)	Not indicated and cannot be easily derived from the indicator building field
Indicator building	• Partnerships: organizations actively engaged
Availability of data	
Feasibility	Insufficient information to judge
Comments/caveats	The concepts used for the indicator building are too complex to derive data collection items
Source of indicator definition	Chandler et al. (2017)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Community building**
Description	Recruitment, on boarding citizens, experts, policy makers
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Publicly available data sources e.g. project deliverables and publications
Time-series	Not specified
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Citizen scientists' self-reports via surveys/questionnaires, focus groups, journaling, public data sources
Data collection item(s)	• How has participating in GROW Observatory enhanced your community? • To what extent has GROW strengthen the communication and networks in your community?
Indicator building	Not specified
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Woods et al. (2019)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Dissemination and feedback**
Description	Dissemination of the project results and informing participants about the ways in which their data have been used
Domain	Society
Qual/Quantitative	Quantitative
Primary/Secondary data	Secondary data
Source of data	Raw classification files and project backups generated by the Zooniverse platform, as well as web analytics for individual projects, blogs, and Twitter feeds
Time-series	No
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Review of project documentation; web analytics for individual projects, blogs, and Twitter feeds
Data collection item(s)	• Number of papers with citizen scientist co-authors • Project age • Number of project Tweets, blog posts, talk posts • Number of science team Talk posts, and blog replies • Project active period
Indicator building	• Collaboration (Total number of papers where the list of authors contains at least one citizen scientist author divided by project age squared) • Communication (Sum total of project communication activity measured across multiple channels divided by project active period squared) • Interaction (Sum total of occurrences of interaction between the science team and volunteers divided by project active period squared)
Availability of data	Low
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Cox et al. (2015)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Community engagement and participation**
Description	Community participation and engagement in health-promotion research
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Publicly available data sources e.g. project deliverables and publications; Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, process, outcomes
Links with indicators in other domains	Governance
Data collection method(s)	Participant surveys, structured interviews with key informants in the community coalitions, event and activities logs, focus groups, observations of meetings, review of existing documents. Literature search
Data collection item(s)	• Who participates and why? • What are the benefits and challenges of community participation? • What qualitative and quantitative methods are used in process evaluations to measure community participation? • What measures are used to help define the influence of community participation in community-based interventions?
Indicator building	• Diversity of participants/organizations • Recruitment/retention of new members • Role in the initiative or its activities • # and type of events attended • Amount of time spent in and outside of initiative activities • Benefits and challenges of participation • Satisfaction with the work or process of participation • Balance of power and leadership.
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	
Source of indicator definition	Butterfoss (2006)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Citizen-led research**
Description	Alignment of project goals to the community demands and efficacy of engagement techniques
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, evaluation at four stages of a project - early stages, mid-project, end of the project, and post-project
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context
Links with indicators in other domains	N/A
Data collection method(s)	(online) self-evaluation questionnaires to be completed at four stages of a project - early evaluation, mid evaluation, end evaluation and post-project evaluation - designed to the profile of the respondents (i.e. civil society members, researchers, students, project managers)
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Community alignment • Responsiveness to community alignment
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	The items listed for the indicator building can be used to derive data collection items in simplistic ways. However, sound implementation would need to draw on scientific research in a number of relevant disciplines.
Source of indicator definition	Gresle et al., (2019)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Participatory dynamics**
Description	Degree and quality of engagement
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, evaluation at four stages of a project - early stages, mid-project, end of the project, and post-project
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Process
Links with indicators in other domains	N/A
Data collection method(s)	(online) self-evaluation questionnaires to be completed at four stages of a project - early evaluation, mid evaluation, end evaluation and post-project evaluation - designed to the profile of the respondents (i.e. civil society members, researchers, students, project managers)
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Motivation • Degree of engagement • Satisfaction with the participatory dynamics
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	The items listed for the indicator building can be used to derive data collection items in simplistic ways. However, sound implementation would need to draw on scientific research in a number of relevant disciplines.
Source of indicator definition	Gresle et al., (2019)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Social and cultural characteristics of a resource**
Description	The diverse ways that communities and individuals interact with the resource, causing the resource to become socially or culturally significant
Domain	Society
Qual/Quantitative	Qualitative
Primary/Secondary data	Secondary data
Source of data	(Publicly available) Project documentation (reports, information on websites, publications etc.)
Time-series	No
Unit of measurement (observation)	Ordinal (High, medium or low ranking)
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	Economy
Data collection method(s)	Review of case studies' documentations
Data collection item(s)	Not indicated and cannot be easily derived from the indicator building field
Indicator building	• Resource perceived as charismatic or ecologically significant • Economic or livelihood reliance on the resource • Social or cultural significance and interaction with the resource • Resource impact on health and well-being of people
Availability of data	Low
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Chase and Levine (2016)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Social inclusion**
Description	Engagement of the public as co-producers of shared, open-source knowledge and technologies
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: project partners/ participants Secondary: Project documentation; social media
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, process, output
Links with indicators in other domains	Governance
Data collection method(s)	Interviews with partners/facilitators; participant surveys/questionnaires; participant observations, Review of project documentations such as events diary (journals) filled in by organizers of events; Participant satisfaction questionnaires filled in by participants attending the event; social media analytics
Data collection item(s)	Fields for information in events diaries for each event: Partner name; Name of event; Brief description (in particular for non-DoA described events); Status (planned / completed / cancelled); Start day, month, year; Event type; Audience number; Percentage female; Work package; Name of partner organization and facilitator person; Participant age bracket; URL 1, 2 and 3; Total amount funding used; Event postcode, town; Duration of the event; Event ID; Reporting period; and Phase (for which the event was planned) Primary data collection items not specified
Indicator building	*Process indicators:* • Considerations/strategies for: - addressing access issues from disadvantaged social groups - ethical issues and values in the design, development and implementation of activities - benefits from activities - design of communication and outreach strategies • # of stakeholders who actively review/show interest in research results that have an impact on social justice *Outcome indicators:* • The % of activities: delivered in accessible locations; modified to address issues of social justice and inclusion; and that may have unintended negative effects on social justice • The percentage of participants attending events from disadvantaged groups *Perception indicators:*

	• Level of importance given to social justice/inclusion • Level of organizational importance & commitment given to development of methodology & implementation of social justice/inclusion strategies • Public belief in the positive & negative impact of activities
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	The suggested perception indictors should be considered as process indicators. The suggested outcomes indicators should be considered as outputs.
Source of indicator definition	DITOs Consortium (2016)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Social capital**
Description	resources needed for resilience at the societal level
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Project partners, participants Secondary: Project documentations (reports, information on websites, publications etc.); Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, input, process, output, outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Interviews with citizen observatory members and non-members stakeholders; review of project documentations (reports, log-books, etc.); analysis of the initiative tools (platforms, Apps, etc.); literature review
Data collection item(s)	8-10 questions are available for each topic in the indicator building - too elaborate to include here
Indicator building	**Formal engagement** • Which community members have a role in formal organizations/institutions (e.g. as spokes persons)? • The score on the indicator for Communication and decision mode in the institutional outcomes • People who volunteered time to an organization in the past month. **Trust and belonging (neighborhood)** • Migration rate in a neighborhood • Perceived 'togetherness' of respondents from the community • People reporting trust in others. **Trust and belonging (online)** • Duration of membership in a relevant online group(s) • Intensity/frequency of posts in the group(s) • Diversity of members participating in that group(s) • People engaging in social networking online. **Helping behaviour** • Frequency and nature of neighbourly help in the community. • Circumstances under which neighbors would ask each other for help. • % of people who believe they can rely on their friends in the case of need
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Societal outcomes**
Description	Enhancing socio-cultural capital to create a sustainable environment
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project coordinator
Time-series	Yes, annual field reports
Unit of measurement (observation)	Ordinal (Low, medium, high)
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	Environment
Data collection method(s)	Review of project reports
Data collection item(s)	Not indicated and cannot be easily derived from the indicator building field
Indicator building	• Livelihood assets enhanced • Cultural heritage components enhanced
Availability of data	Low
Feasibility	Insufficient information to judge
Comments/caveats	The concepts used for the indicator building are too complex to derive data collection items
Source of indicator definition	Chandler et al. (2017)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Societal outcomes related to human health**
Description	Community-level indicators to assess the societal outcomes related to human health
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Publicly available data sources e.g. project deliverables and publications
Time-series	Not specified
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	Governance
Data collection method(s)	Citizen scientists' self-reports via surveys/questionnaires, focus groups, journaling, public data sources
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Social behaviour • Welfare • Quality of life
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Woods et al. (2016)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Societal outcomes**
Description	Societal outcomes of community engagement in an Academic Medical Centre
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: project partners, participants Secondary: review of documents
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	Science & tech.
Data collection method(s)	Review of documents (e.g., activity logs, minutes); interviews with key individuals (practitioners, community, and national scientific leaders); quantitative surveys of practitioners; observations
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Improvement in the health of community • Change in credibility/trust (in AMC) • Increase in generalizable knowledge and practices
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	
Source of indicator definition	Szilagyi et al. (2014)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Societal knowledge exchange outcomes**
Description	Outcomes of generating, sharing, and/or using knowledge through various methods in an interdisciplinary and multi-stakeholder setting
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Participants Secondary: Review of project documentations
Time-series	Yes, mid-project assessment of knowledge exchange processes and ex post evaluation of results
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Surveys and interviews with participants to evaluate changes in understanding and process-based outcomes; Observation; Review of project documentations (e.g. reports, activity records, meeting minutes); Literature review (Peer-reviewed, grey or professional literature)
Data collection item(s)	Not indicated, but can be derived using the following examples: • Mothers' knowledge of causes, symptoms and treatments of malaria; ecological awareness of students • Ability to create good questions as assessed by self, peers and teacher; personal research skill development • Change in perceived feasibility and importance of smoking cessations; attitude towards plantation forestry industry • Intentions to engage in CoP-building activities; commitment to act • Self-efficacy of patients in speaking to doctors; feeling of greater security and equality as care giver • Quantity and quality of the ideas resulting from the creative process • Shared understanding; consensus on the topic; fishing agreement in place; less intervillage conflict; communication and collaboration is increased; trust has increased between partners • Complete information
Indicator building	• Increased knowledge, awareness or understanding • New skills learned by participants • Attitude change • Intention of behaviour change • Creation of innovations and new Ideas • Provision of information • New networks or structures • Improved communication
Availability of data	Low
Feasibility	Resource demanding

Comments/caveats	The items listed for the indicator building can be used to derive data collection items in simplistic ways. However, sound implementation would need to draw on scientific research in a number of relevant disciplines.
Source of indicator definition	Fazey et al. (2014)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Societal impact**
Description	Societal changes resulting from the project
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Not specified
Data collection item(s)	• What are the societal goals of the project and how are they communicated? • Does the project foster resilience and collective capacity for learning and adaptation? • Does the project foster social capital? • Does the project stimulate political participation? • Does the project have any impact on political decisions?
Indicator building	• Collective capacity, social capital • Political participation
Availability of data	low
Feasibility	Insufficient information to judge
Comments/caveats	
Source of indicator definition	Kieslinger et al. (2017; 2018)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Distribution of risks**
Description	Distribution of adverse effects among different groups in society
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Project partners, participants Secondary: Project documentations (reports, information on websites, publications etc.); Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, input, process, output, outcome, impact
Links with indicators in other domains	Economy
Data collection method(s)	Interviews with citizen observatory members and non-members stakeholders; review of project documentations (reports, log-books, etc.); analysis of the initiative tools (platforms, Apps, etc.); literature review
Data collection item(s)	8-10 questions are available for each topic in the indicator building - too elaborate to include here
Indicator building	**Distribution of resources** • Gap between people with the highest and the lowest income • Distribution of creative and flexible capacities • Distribution of access to information and potential help • Gini coefficient of household disposable income and gap between richest and poorest 10%. **Digital divide** • Distribution of Digital Savviness • Perceived level of own digital skills • Availability of internet connection (mobile, fixed) • Proportion of individuals who own a mobile telephone, by sex (SDG 5.b.1) • Proportion of individuals using the Internet (SDG 17.8.1) **Distribution of adverse effects** • (Availability of) impact maps of relevant region • Perceived distribution of potential impacts • Direct disaster economic loss in relation to global GDP (SDG 1.5.2)
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Environmental risk perception**
Description	Perceptions about the likelihood and impact of environmental risks
Domain	Environment
Qual/Quantitative	Quantitative
Primary/Secondary data	Secondary data
Source of data	World Economic Forum, The Global Risks Report, https://www.weforum.org/reports
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Review of available online resources (The Global Risks Report)
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Perceptions of environmental risks (likelihood, impact) • Perceptions of extreme weather events (likelihood, impact) • Perceptions of climate change (likelihood, impact) • Perception of water crises (likelihood, impact)
Availability of data	Low-medium
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Information**
Description	Access to dependable and complete information
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Project partners, participants Secondary: Project documentations (reports, information on websites, publications etc.); Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, input, process, output, outcome, impact
Links with indicators in other domains	Governance
Data collection method(s)	Interviews with citizen observatory members and non-members stakeholders; review of project documentations (reports, log-books, etc.); analysis of the initiative tools (platforms, Apps, etc.); literature review
Data collection item(s)	8-10 questions are available for each topic in the indicator building - too elaborate to include here
Indicator building	**Shared stories** • Diversity of the opinions about the topic of the observatory: level of consensus on implications, causes, etc. • The awareness or urgency for the topic of the observatory among the involved community members • Intensity of social conflicts (excluding conflicts relating to land) **Trusted sources** • The awareness of residents of the available official information sources (about the issue of the observatory). • The amount and distribution of other (non-)trustworthy information sources. • The information that community members use to base their opinions on. • People reporting to be not at all interested in politics **Timely and accurate information** • The location-specificity of the available information on the observatory topic • The time intervals in which is the available information is being distributed. The correlation of that with the speed at which reality changes. • The channels through which the information is shared with the public and the part of the community that is reached. • Internet use by type of activity Individuals using the Internet from any location
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	

Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Capacity building**
Description	Changes in individual and organizational capacity for participation
Domain	Society
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: project partners, participants Secondary: Project documentation; social media
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, process, output
Links with indicators in other domains	
Data collection method(s)	Interviews with partners/facilitators; participant surveys/questionnaires; participant observations, Review of project documentations such as events diary (journals) filled in by organizers of events; Participant satisfaction questionnaires filled in by participants attending the event; social media analytics
Data collection item(s)	Fields for information in events diaries for each event: Partner name; Name of event; Brief description (in particular for non-DoA described events); Status (planned / completed / cancelled); Start day, month, year; Event type; Audience number; Percentage female; Work package; Name of partner organization and facilitator person; Participant age bracket; URL 1, 2 and 3; Total amount funding used; Event postcode, town; Duration of the event; Event ID; Reporting period; and Phase (for which the event was planned) Primary data collection items not specified
Indicator building	<u>*Process indicators:*</u> • # of facilitators / science communicators • Current experience & training opportunities for facilitators <u>*Outcome indicators:*</u> • # of collaborations & types • # & type of participant-initiated/led activities • # & types of skills developed by participants & facilitators • Costs of (increased) organizational capacity <u>*Perception indicators:*</u> • Understanding of science & technology • Attitude towards science & technology • Attitude towards their own abilities
Availability of data	Low
Feasibility	Moderately resource demanding

Comments/caveats	The suggested perception indictors should be considered as process indicators. The suggested outcomes indicators should be considered as outputs.
Source of indicator definition	DITOs Consortium (2016)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Awareness and responsibility**
Description	Protect and enhance natural resources through direct action and awareness raising
Domain	Environment
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	Not specified
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	Society
Data collection method(s)	not specified
Data collection item(s)	• Does the project contribute to higher awareness and responsibility for the natural environment?
Indicator building	Not specified
Availability of data	Low
Feasibility	Insufficient information to judge
Comments/caveats	The first data collection item for this indicator (re. protect and enhance natural resources) has been included in the environment domain (ecological impact).
Source of indicator definition	Kieslinger et al. (2017; 2018)

Society - Indicators ID	
Indicator characteristics	
Aggregate indicator name	**Environmental education and stewardship**
Description	Individual and societal outcomes in terms of education and stewardship
Domain	Society
Qual/Quantitative	Quantitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Interviews with participants in training sessions
Data collection item(s)	To what degree you feel the [name of the program] volunteers are making a difference in their communities in different ways? (see the indicator building filed) Ranking on a scale of 0 (none) to 100 (a lot)
Indicator building	• Participating in environmental stewardship projects • Educating and engaging the public • Creating knowledgeable and credible volunteers in the local community • Generating advocates for natural resource agencies; Increasing self-confidence of volunteers • Developing community through social connections
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Merenlender et al. (2016)

Annex 7 Science & Technology domain - reviewed indicators

Domain	Indicator Cluster	Indicator Name
Science & Technology	Data collection and management	Data Data and systems Enhanced data
	Collaboration in science	Collaboration and synergies Scientific impact Community participation in research
	Contribution to science	Scientific contribution (1) Scientific contribution (2) Scientific value of data Written material Knowledge democracy Scientific objectives
	Decision making	Management and Policy Scientific outcomes
	Communication and outreach	Communication material Science initiatives & events Evaluation and adaptation

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Data**
Description	Raw data and value-added data products created and distributed for use by others
Domain	Science & Technology
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Secondary data
Source of data	(Publicly available) project documentations
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Output
Links with indicators in other domains	n/a
Data collection method(s)	Review of project of documentation and publications; analysis of project tools

Data collection item(s)	Not indicated, but can be derived from the following definitions: • Existence of technologies for automated data exchange between computers • Number of curated exports of data and related documentation, usually as a downloadable file • Existence of documentation describing data structure, formats, and contents • Existence of visual representations of data, such as graphs, maps, and animations • Number of material data points in the form of physical specimens or samples • Number of individuals or technical systems requesting data, or volume of transferred data
Indicator building	• APIs (Y/N) • Data packages (#) • Metadata (Y/N) • Visualizations (Y/N) • Specimens/samples (#) • Requests (# requests, transfer volume)
Availability of data	Medium-high
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Wiggins et al. (2018)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Data and systems**
Description	Improvement in data quantity, quality and accessibility
Domain	Science & Technology
Qual/Quantitative	Qualitative and quantitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Process & output
Links with indicators in other domains	N/A
Data collection method(s)	Not specified
Data collection item(s)	• Does the project have clear processes defined to validate and guarantee high data quality? • Does the data adhere to common standards? • Does the project have a data management plan, IPR strategy and ethical guidelines? • Are data ownership and access rights clear and transparent? • Is the data handling process transparent? • Do citizens know what the data is used for, and where it is stored and shared? • Does the project have open interfaces to connect to other systems and platforms? • Is the generated data shared publicly and if so, under which conditions? • Is the project data appropriately archived for future analysis?
Indicator building	• Data quality and standards • Ethics, data protection, Intellectual Property Rights (IPR) • Openness, interfaces
Availability of data	low
Feasibility	Insufficient information to judge
Comments/caveats	
Source of indicator definition	Kieslinger et al. (2017; 2018)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Enhanced data**
Description	Enhancement of data collection
Domain	Science & Technology
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Not specified
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Results (outputs, outcomes and impacts)
Links with indicators in other domains	n/a
Data collection method(s)	Not specified
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Data coverage • Resolution (spatial, temporal and taxonomic) of data • Accuracy of data • Inter-disciplinarily of data sources
Availability of data	Low
Feasibility	Insufficient information to judge
Comments/caveats	
Source of indicator definition	Pocock et al. (2018)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Collaboration and synergies**
Description	Creation of new collaboration opportunities and synergies
Domain	Science & Technology
Qual/Quantitative	Qualitative and quantitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, process, outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Not specified
Data collection item(s)	• Does the project collaborate with other initiatives at the (inter-) national level to enhance mutual learning? • Does the project link to experts from other disciplines?
Indicator building	Not specified
Availability of data	low
Feasibility	Insufficient information to judge
Comments/caveats	
Source of indicator definition	Kieslinger et al. (2017; 2018)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Scientific impact**
Description	The scientific impact(s) of projects
Domain	Science & Technology
Qual/Quantitative	Qualitative and quantitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Output and outcome
Links with indicators in other domains	N/A
Data collection method(s)	Not specified
Data collection item(s)	• Does the project demonstrate an appropriate publication strategy, both in scientific and other media outlets? • Are citizen scientists recognized in publications and if so, can they participate in the dissemination of results? • Did the project generate new research questions, projects or proposals? • Did the project contribute to any institutional or structural changes? • Does the project ease access to traditional and local knowledge resources? • Does the project contribute to a better understanding of science in society?
Indicator building	• Scientific knowledge and publications • New fields of research and research structures • New knowledge resources
Availability of data	low
Feasibility	Insufficient information to judge
Comments/caveats	The data collection items are incoherent and don't match items at the indicator building level
Source of indicator definition	Kieslinger et al. (2017; 2018)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Community participation in research**
Description	Measures of community partners involvement in research process
Domain	Science & Technology
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Project coordinator and partners Secondary: Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Process
Links with indicators in other domains	Society
Data collection method(s)	Semi structured interviews with Principle investigators of projects; survey with academic and community partners working on projects; review of literature on community-academic partnerships
Data collection item(s)	In which specific research activities (and to what extent) community partner were involved? - Grant proposal writing - Background research - Choosing research methods - Developing sampling procedures - Recruiting study participants - Implementing the intervention - Designing interview and/or survey questions - Collecting primary data - Analyzing collected data - Interpreting study findings - Writing reports and journal articles - Giving presentations at meetings and conferences
Indicator building	• Specific research activities that community partners participated in • The extent to which the community partners participated in the research components (scale between 0 and 12)
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Khodyakov et al. (2013)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Scientific contribution (1)**
Description	Measures of scientific contribution of a project or initiative
Domain	Science & Technology
Qual/Quantitative	Qualitative and quantitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Online repositories (e.g. Science Direct, Google Scholar, etc.); Social media analytics
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outputs
Links with indicators in other domains	n/a
Data collection method(s)	Online surveys, interviews, and focus groups with projects participants, as well as usage statistics
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• # of papers published • # of citations • # of grants received • Size and quality of citizen science databases • # of theses • Frequency of media exposure
Availability of data	Medium-high
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Bonney et al. (2009a)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Scientific contribution (2)**
Description	Increasing scientific knowledge to facilitate and disseminate world class scientific field research
Domain	Science & Technology
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project coordinator
Time-series	Yes, annual field reports
Unit of measurement (observation)	Ordinal (Low, medium, high)
Unit of analysis	Project
Analytical level (logic model)	Not specified
Links with indicators in other domains	n/a
Data collection method(s)	Review of project reports
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• # of people and # of person hours dedicated to collecting scientific data • Peer reviewed publications • Popular publications and outreach events
Availability of data	Low
Feasibility	Slightly resource demanding
Comments/caveats	
Source of indicator definition	Chandler et al. (2017)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Scientific value of data**
Description	The scientific value of the data generated by the project
Domain	Science & Technology
Qual/Quantitative	Quantitative
Primary/Secondary data	Secondary data
Source of data	Raw classification files and project backups generated by the Zooniverse platform, as well as web analytics for individual projects, blogs, and Twitter feeds
Time-series	No
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Review of project documentations; web analytics for individual projects, blogs, and Twitter feeds
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Publication Rate • Completeness of Analysis • Academic Impact
Availability of data	Low
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Cox et al. (2015)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Written material**
Description	Formal and informal written products
Domain	Science & Technology
Qual/Quantitative	Quantitative
Primary/Secondary data	Secondary data
Source of data	(Publicly available) project documentations; Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	No
Unit of measurement (observation)	Nominal
Unit of analysis	Project
Analytical level (logic model)	Output
Links with indicators in other domains	n/a
Data collection method(s)	Review of project documentation and publications; analysis of project tools
Data collection item(s)	Not indicated, but can be derived from the following definitions: • Number of theses and dissertations using data from or reporting on the project • Number of published peer-reviewed science papers that report on the project or apply its data • Number of formal reports reporting results, such as white papers, technical, and other reports • Existence (or total monetary value) of competitive funding awards from private or public funders
Indicator building	• Dissertations, theses (#) • Scholarly publications (#) • Reports (#) • Grants awarded (#, $)
Availability of data	Medium-high
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Wiggins et al. (2018)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Knowledge democracy**
Description	Transdisciplinary and relevance of topics
Domain	Science & tech.
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, evaluation at four stages of a project - early stages, mid-project, end of the project, and post-project
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, process, outcomes
Links with indicators in other domains	N/A
Data collection method(s)	(online) self-evaluation questionnaires to be completed at four stages of a project - early evaluation, mid evaluation, end evaluation and post-project evaluation - designed to the profile of the respondents (i.e. civil society members, researchers, students, project managers)
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Scientific relevance • Openness • Transdisciplinary
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Gresle et al., (2019)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Scientific objectives**
Description	Relevance of scientific problem
Domain	Science & Technology
Qual/Quantitative	Qualitative and quantitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context & process
Links with indicators in other domains	Society
Data collection method(s)	Not specified
Data collection item(s)	• Are the scientific goals sufficiently clear and authentic? • Is the scientific objective appropriate to citizen science? • Does the project adhere to the principle of joint knowledge creation in citizen science? • Does the scientific objective have relevance for society and does it address a socially relevant problem?
Indicator building	Not specified
Availability of data	low
Feasibility	Insufficient information to judge
Comments/caveats	
Source of indicator definition	Kieslinger et al. (2017; 2018)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Management and Policy**
Description	Direct actions, decision-support products, and policy impacts from citizen-science projects
Domain	Science & Technology
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Secondary data
Source of data	(Publicly available) project documentations
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome
Links with indicators in other domains	Governance
Data collection method(s)	Review of project of documentation and publications; analysis of project tools
Data collection item(s)	Not indicated, but can be derived from the following definitions: • Existence of legal rulings or regulation enforcement based on project data and findings • Existence of decisions based on project data and findings (e.g., for policy or management) • Existence of models based on project data that simulate or predict complex phenomena
Indicator building	• Regulatory action (Y/N) • Decision support (Y/N) • Forecasting/models (Y/N) • Blogs (Y/N)
Availability of data	Medium-high
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Wiggins et al. (2018)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Scientific outcomes**
Description	Added value of citizen-contributed data for scientific purposes
Domain	Science & Technology
Qual/Quantitative	Quantitative
Primary/Secondary data	Primary data
Source of data	Participants
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Interviews with participants in training sessions
Data collection item(s)	Supporting question: Please rank on a scale of 0 (none) to 100 (a lot) to what degree you feel the [name of the program] volunteers are making a difference in their communities in each of the following ways: - Contributing data through citizen science to inform research or management - Supporting work of natural resource professionals
Indicator building	• Data contribution to inform research or management • Support the work of natural resource professionals
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Merenlender et al. (2016)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Communication material**
Description	Public discourse and science communication products
Domain	Science & Technology
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Secondary data
Source of data	(Publicly available) project documentations; Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Output
Links with indicators in other domains	n/a
Data collection method(s)	Review of project of documentation and publications; analysis of project tools
Data collection item(s)	Not indicated, but can be derived from the following definitions: • Existence of online informal written communications about project processes and findings • Existence of structured publications for project stakeholders, produced in hard copy or digitally • Existence of publicly available digital videos on project content, activities, and findings • Existence (or number) of oral presentations at conferences or public events • Existence of dedicated website for the project
Indicator building	• Newsletters (Y/N) • Videos (Y/N) • Presentations (Y/N) • Website (Y/N)
Availability of data	Medium-high
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Wiggins et al. (2018)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Science initiatives & events**
Description	Details about the process and outcomes of science-related initiatives and events
Domain	Science & Technology
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: project partners/ participants Secondary: Project documentation; social media
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context, process, output
Links with indicators in other domains	Society
Data collection method(s)	Interviews with partners/facilitators; participant surveys/questionnaires; participant observations, Review of project documentations such as events diary (journals) filled in by organizers of events; Participant satisfaction questionnaires filled in by participants attending the event; social media analytics
Data collection item(s)	Fields for information in events diaries for each event: Partner name; Name of event; Brief description (in particular for non-DoA described events); Status (planned / completed / cancelled); Start day, month, year; Event type; Audience number; Percentage female; Work package; Name of partner organization and facilitator person; Participant age bracket; URL 1, 2 and 3; Total amount funding used; Event postcode, town; Duration of the event; Event ID; Reporting period; and Phase (for which the event was planned)
Indicator building	*Process indicators:* • # & type of Initiatives • # & types of locations for science events *Outcome indicators:* • # of visitors / participants at activities • Types of visitors / participants • Social media coverage *Perception indicators:* • Perceived 'level' of participation/contribution • Attitude toward facilitator & organization
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	The suggested perception indictors should be considered as process indicators. The suggested outcomes indicators should be considered as outputs.

Source of indicator definition	DITOs Consortium (2016)

Science & technology - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Evaluation and adaptation**
Description	Existence of evaluation, feedback and reflection procedures
Domain	Science & Technology
Qual/Quantitative	Qualitative and quantitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Context & process
Links with indicators in other domains	Society
Data collection method(s)	Not specified
Data collection item(s)	• Does the project have a sound evaluation concept, considering scientific as well as societal outcomes? • Does the evaluation concept include indicators regarding the impact on individual participants and users of the project results? • Is evaluation planned at strategic points of the project?
Indicator building	• Project evaluation • Adaptive project management • Are project structures adaptive and reactive, including feedback loops for adaptation, and possibly a scoping phase? • Does the project have an appropriate risk management plan?
Availability of data	low
Feasibility	Insufficient information to judge
Comments/caveats	
Source of indicator definition	Kieslinger et al. (2017; 2018)

Annex 8 Governance domain - reviewed indicators

Domain	Indicator Cluster	Indicator Name
Governance	Participation	Participation dynamics
		Institutional commitment to public engagement
	Power dynamics	Power dynamics within CS initiative
		Change in power relations
	Impact on policy	Institutional setup
		Contributions to management plans and policy
		Shift in policy and regulations
		Change in policies & practices
	Equality and inclusion	Gender equality

Governance - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Participation dynamics
Description	Who participates in the decision making process (via the citizen observatory) and how?
Domain	Governance
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Project partners, participants Secondary: Project documentations (reports, information on websites, publications etc.); Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	stakeholder groups & publications
Analytical level (logic model)	Context, input, process, output, outcome, impact
Links with indicators in other domains	Society
Data collection method(s)	Interviews with members of the initiative and non-members stakeholders; review of project documentations (reports, log-books, etc.); analysis of the initiative tools (platforms, Apps, etc.); literature review
Data collection item(s)	Interview questions are available but too elaborate to add here

Indicator building	**<u>Geographic scope</u>** • Geographic scope of the issue in focus • Location of stakeholders (inside/outside the geographic boundaries) **<u>Participant groups</u>** • Demographic characteristics of the population • Composition of stakeholders involved in decision making process in focus of initiative **<u>Efforts required to participate</u>** • Time (hours/month) required for participation • Equipment required for participation • Infrastructure required for participation • Knowledge required for participation • Skills required for participation • Investment required for participation; capital (€) and long term (€/month) **<u>Support offered for participation</u>** • Type of material support provided for participants (e.g. manuals, instructions, training, sensor devices, etc.) • Perception of the users about the flexibility of the participation methods • Type of incentives offered to encourage different participant groups **<u>Communication paradigm</u>** • Channels of data and information flow between different stakeholders • The pattern of information flow ('unidirectional', 'bi-directional' and 'interactive') between different stakeholders **<u>Communication and decision mode</u>** • Mechanisms for stakeholder interactions in decision making process-es (e.g. data provision, expressing preferences, deliberation and negotiation, etc.) **<u>Impact indicators</u>** • Change in percentage of population who believe decision-making at all levels is inclusive and responsive • Change in participation in political processes and civic engagement at local level • Change in proportion of public funds allocated to public participation in decision making; Civil society organizations • Change in proportion of individuals who used the internet for interaction with public authorities
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	The indicator building cell includes process, outcome and impact indicators
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Governance - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Institutional commitment to public engagement
Description	Commitments by institutions and organizations to public engagement
Domain	Governance
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: project partners/ participants Secondary: Project documentation; social media
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project/program
Analytical level (logic model)	Context, input, process, output, outcome, impact, and perception indicators
Links with indicators in other domains	n/a
Data collection method(s)	Interviews with partners/facilitators; participant surveys/questionnaires; participant observations, Review of project documentations such as events diary (journals) filled in by organizers of events; Participant satisfaction questionnaires filled in by participants attending the event; social media analytics
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	*Process indicator:* • Commitments by institutions & organizations to public engagement *Outcome indicator:* • Changes in agendas / organizational practices as a result from public engagement *Perception indicators:* • Public interest in impact of science & technology • Public expectations of engagement in decision-making processes
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	DITOs Consortium (2016)

Governance - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Power dynamics within CS initiative
Description	Control and influence over the issue in focus of the citizen observatory
Domain	Governance
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Project partners, participants Secondary: Project documentations (reports, information on websites, publications etc.); Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	stakeholder groups & publications
Analytical level (logic model)	Context, input, process, output, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Interviews with members of the initiative and non-members stakeholders; review of project documentations (reports, log-books, etc.); analysis of the initiative tools (platforms, Apps, etc.); literature review
Data collection item(s)	Interview questions are available but too elaborate to add here
Indicator building	**Revenue stream** • The (envisioned) revenue stream(s) that help cover the expenses for running the CO **Access to and control over data** • Access restrictions to the data for different stakeholder groups • The procedures for storing, quality control, visualization of the data (Data Management Plan and policies) **Authority and power** • The level of influence/impact of each stakeholder on the results of the decision making processes regarding the environmental problem in focus • Change in the level of authority and power of each stakeholder as result of participation in the CO **Impact indicators** • Percentage of budget documents, of budget revenue documents, procurement and natural resource concessions publicly available and easily accessible in open data format • Turnout as a share of voting-age population in national election
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	The indicator building cell includes both outcome and impact indicators

Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Governance - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Change in power relations
Description	Change in power relations that facilitates communities to express their voices
Domain	Governance
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Primary: Project partners, participants
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project/initiative
Analytical level (logic model)	No
Links with indicators in other domains	n/a
Data collection method(s)	(web-based) surveys completed by the CBPR Principal Investigator (PI) and participants; interviews with participants; focus-group discussions with local and national partnerships, observations
Data collection item(s)	Our partnership reflects on issues of power and privilege within our partnership [7 point scale: completely disagree - completely agree] Power relations: How much do you agree or disagree that community members…[7 point scale: completely disagree - completely agree] - Have increased participation in the research process - Can voice their opinions about research in front of researchers - Have the power to promote research that will benefit the community
Indicator building	Not specified
Availability of data	Low
Feasibility	Slightly resource demanding
Comments/caveats	
Source of indicator definition	Lucero et al. (2018)

Governance - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Institutional setup
Description	Institutional and political context
Domain	Governance
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: Project partners, participants Secondary: Project documentations (reports, information on websites, publications etc.); Online repositories (e.g. Science Direct, Google Scholar, etc.)
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	stakeholder groups & publications
Analytical level (logic model)	Context, output, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Interviews with members of the initiative and non-members stakeholders; review of project documentations (reports, log-books, etc.); analysis of the initiative tools (platforms, Apps, etc.); literature review
Data collection item(s)	Interview questions are available but too elaborate to add here
Indicator building	**Formal institutions and policies** • National or sub-national laws and regulations that assigns and distinguishes competent authorities related to the environmental problem in focus • National or sub-national policy related to the environmental problem in focus • Binding international or supranational frameworks related to the environmental problem in focus **Informal institutions** • Value, norms, and traditions related to managing the environmental problem in focus • Influential (non-governmental) local leaders • Alternative methods of influencing the decisions (e.g. protests) **Multilevel interactions of actors, organizations, and institutions** • Co-ordination mechanisms across different governmental levels (e.g. between ministries, across central and national government, and local government) • Co-ordination mechanisms between governmental and non-governmental stakeholders **Possible plural legal systems** • Existence of plural legal systems (formal & informal) with regards to the environmental problem in focus **Impact indicators**

	• Existence of constituencies (mechanisms or bodies) and enforcement agencies (e.g., youth, women, traditional leaders) to ensure consultative, bottom-up process of representation in decision making • Existence and enforcement of legislation for ensuring representation of specific groups • Proportion of population satisfied with their last experience of public services, disaggregated by service • Perception of failure of regional and global governance • Perception of failure of national governance
Availability of data	Low
Feasibility	Resource demanding
Comments/caveats	The indicator building cell includes both outcome and impact indicators
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Governance - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Contributions to management plans and policy
Description	Informing environmental policies, agendas, management plans and government policies through
Domain	Governance
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project coordinator
Time-series	Yes, annual field reports
Unit of measurement (observation)	Low, medium, high (based on both absolute values & nominal)
Unit of analysis	Project
Analytical level (logic model)	Not specified
Links with indicators in other domains	n/a
Data collection method(s)	Field reports submitted by Principal Investigators
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Contributions to conventions, agendas, policies, and management plans • Pro-environment actions taken at the research project site
Availability of data	Low
Feasibility	Slightly resource demanding
Comments/caveats	
Source of indicator definition	Chandler et al. (2017)

Governance - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Shift in policy and regulations
Description	Changes observed outside the communities of interest and practice themselves
Domain	Governance
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Publicly available data sources e.g. project deliverables and publications
Time-series	Not specified
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project/initiative
Analytical level (logic model)	Context, output, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Citizen scientists' self-reports via surveys/questionnaires, focus groups, journaling, public data sources
Data collection item(s)	Broad question: Have there been policy changes as a result of the intervention?
Indicator building	• New or modified service or programmes • Changes in policies, such as a new or modified policy
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	
Source of indicator definition	Woods et al. (2016)

Governance - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Change in policies & practices
Description	Formal and informal processes and outcomes related to policies and practices are changed
Domain	Governance
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Primary: Project partners, participants
Time-series	No
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project/initiative
Analytical level (logic model)	No
Links with indicators in other domains	n/a
Data collection method(s)	(web-based) surveys completed by the CBPR Principal Investigator (PI) and participants; interviews with participants; focus-group discussions with local and national partnerships, observations
Data collection item(s)	As a result of this partnership, have any (IRB) policy, procedures, or practices been developed or revised? [check all that apply: developed/revised/neither] Were there other institutional policies or practices that were changed as a result of this study or partnership? [yes/no/don't know] Please describe the institutional policies or practices that were changed as a result of this study or partnership. [open field] Matrix with six-point scale answer [not at all - to a complete extent]: Better coordination betw. agencies, researchers and community groups Changes in the nature of debates about important health issues in the community Useful findings for the development of community practices, programs or policies Changes in policy
Indicator building	Not specified
Availability of data	Low
Feasibility	Slightly resource demanding
Comments/caveats	
Source of indicator definition	Lucero et al. (2018)

Governance - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Gender equality
Description	Equal participation of males and females; Gender perspective on science & technology content
Domain	Governance
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	
Source of data	Primary: project partners, participants Secondary: Project documentation; social media
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project/program
Analytical level (logic model)	Context, input, process, output, outcome, impact, and perception indicators
Links with indicators in other domains	n/a
Data collection method(s)	Interviews with partners/facilitators; participant surveys/questionnaires; participant observations, Review of project documentations such as events diary (journals) filled in by organizers of events; Participant satisfaction questionnaires filled in by participants attending the event; social media analytics
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	<u>*Process indicator:*</u> • Gender equality commitments / frameworks • # & type of events discussing gender dimension in science & technology* <u>*Outcome indicator:*</u> • % of women attending events • % of women in Advisory Boards • % of women facilitators & collaborators • % of women initiating/leading citizen initiatives • % of women sharing feedback <u>*Perception indicators:*</u> • General perception of gender equality issues in science & technology Perception/awareness of gender equality efforts / initiatives in science & technology • Perception/awareness of gender equality issues in science & technology relevant to their own lives
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	

Source of indicator definition	DITOs Consortium (2016)

Annex 9 Environment domain - reviewed indicators

<table>
<tr><td rowspan="6">Environment</td><td rowspan="3">Natural resources and biodiversity</td><td>Biodiversity of flora, fauna and landscapes</td></tr>
<tr><td>Biophysical and geographical characteristics of natural resources</td></tr>
<tr><td>Quality of natural resources/ fighting pollution</td></tr>
<tr><td rowspan="3">Environment & society</td><td>Environmental impact on human health* (env. conditions)</td></tr>
<tr><td>Natural and socio-cultural capital</td></tr>
<tr><td>Ecosystem and resilience</td></tr>
</table>

Environment - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Biodiversity of flora, fauna and landscapes
Description	The state of flora and fauna species
Domain	Environment
Qual/Quantitative	Quantitative
Primary/Secondary data	Secondary data
Source of data	Organization for Economic Cooperation and Development, stats.oecd.org
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Country
Analytical level (logic model)	Context, input, process, output, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Review of available online resources (OECD reports) Citizen-contributed data
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Threatened species as % of known species
Availability of data	Low-medium
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Environment - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Biophysical and geographical characteristics of natural resources
Description	Context-related indicators of biophysical and geographical characteristics of natural resources
Domain	Environment
Qual/Quantitative	Qualitative
Primary/Secondary data	Secondary data
Source of data	(Publicly available) Project documentations (reports, information on websites, publications etc.)
Time-series	No
Unit of measurement (observation)	Ordinal (High, medium or low ranking)
Unit of analysis	Project
Analytical level (logic model)	Context
Links with indicators in other domains	n/a
Data collection method(s)	Review of case studies' documentation
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Geographic scale • Range of resource • Life cycle of species • Accessibility and visibility of species • Proximity of species to populated areas
Availability of data	Low
Feasibility	Slightly resource demanding
Comments/caveats	Arguably, the indicator would typically be monitored via CS activities rather than extracting data from case study documentation.
Source of indicator definition	Chase and Levine (2016)

Environment - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Quality of natural resources/ fighting pollution
Description	Quality of natural resources such as water, soil, air, etc, as well as contribution to fighting pollution
Domain	Environment
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Secondary data
Source of data	- OECD Better Life Index: Environment, http://www.oecdbetterlifeindex.org
Time-series	Yes, ex ante and ex post
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Country
Analytical level (logic model)	Context, input, process, output, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Review of available online resources (OECD Better Life Index, and OECD Regional Social and Environmental indicators) Citizen-contributed data
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Quality of specific natural resources • % of people reporting to be satisfied with the quality of local water • Average concentration of particulate matter (PM2.5) in the air • Net ecosystem productivity measured by CO_2 sequestration or release
Availability of data	Low-medium
Feasibility	Minimal resources required
Comments/caveats	
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Environment - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Environmental impact on human health*
Description	Community-level indicators to assess the environment's impact on human health
Domain	Environment
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Primary: participants Secondary: Publicly available data sources e.g. project deliverables and publications
Time-series	Not specified
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project/initiative
Analytical level (logic model)	Context, output, outcome, impact
Links with indicators in other domains	n/a
Data collection method(s)	Citizen scientists' self-reports via surveys/questionnaires, focus groups, journaling, public data sources
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• The amount and condition of open space in the community (including public parks, conservation land and other protected areas, wildlife refuges, state forest, farmland, and (un) protected wild areas) • Amount of protected land in the community • Efforts to preserve and restore historic buildings, monuments, spaces, etc. • The quality and adequacy of drinking water in the community (measurable pollutants, threats to or problems with the water source, size of the water supply and its ability to meet future needs, etc.) • Air quality in the community • Efforts by local government to reduce its effect on the environment (e.g., mandated use of low-emissions vehicles on government business, low-emissions or electric vehicles used for public transportation and garbage pickup) • Availability and ease of recycling of paper, plastic, hazardous waste, and metal for both households and business/industry • Level of regulation and enforcement of environmental standards for business and industry • Local sponsorship of or support for public art (e.g., sculpture in public spaces, murals painted by teenagers in neighborhoods)
Availability of data	Low
Feasibility	Moderately resource demanding
Comments/caveats	This indicator doesn't measure what the title indicates. It measures environmental conditions that can have implications for human health

Source of indicator definition	Woods et al. (2016)

Environment - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Natural and socio-cultural capital
Description	Enhancing natural and socio-cultural capital to create a sustainable environment
Domain	Environment
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project coordinator
Time-series	Yes, annual field reports
Unit of measurement (observation)	Ordinal (Low, medium, high)
Unit of analysis	Project
Analytical level (logic model)	Not specified
Links with indicators in other domains	Society
Data collection method(s)	Field reports submitted by Principal Investigators
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	• Taxa of conservation significance enhanced • Natural habitats enhanced • Ecosystem services enhanced • Cultural heritage components enhanced • Livelihood assets enhanced
Availability of data	Low
Feasibility	Slightly resource demanding
Comments/caveats	
Source of indicator definition	Chandler et al. (2017)

Environment - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	Ecosystem and resilience
Description	Improved conservation action leading to better environment
Domain	Environment
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Not specified
Time-series	No
Unit of measurement (observation)	Absolute values
Unit of analysis	Project
Analytical level (logic model)	Outcome and impact
Links with indicators in other domains	n/a
Data collection method(s)	Not specified
Data collection item(s)	Not indicated, but can be derived from the 'indicator building' field
Indicator building	•Improved conservation action leading to better environment including: • Improved ecosystem function • Improved ecosystem services • Improved resilience
Availability of data	Low
Feasibility	Insufficient information to judge
Comments/caveats	Theoretical framework presented in this publication has not been applied.
Source of indicator definition	Pocock et al. (2018)

Annex 10 Economy domain - reviewed indicators

Domain	Indicator Cluster	Indicator Name
Economy	Supply side	Company growth
		International trade & investment
		Innovation & research
		Competitiveness
		Economic potential and market opportunities
	Demand side	Employment
		Conduct of business
		Value added for organizations

Economy - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Company growth**
Description	Change in factors that indicate growth of a company, because of involvement in a CS project
Domain	Economy
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project partners, participants
Time-series	Yes, ex-ante/ex-post survey
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Organization
Analytical level (logic model)	Context, input, output, outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Questionnaire that was filled in by project partners twice to collect data about baseline and economic impacts of the COs
Data collection item(s)	• How many jobs are currently directly related to [CO topic] and enabling technologies? • What is the nature of these jobs? (junior, medior, senior position(s)) [nominal] • How many of your products/services are relevant for the provision of COs? • What was your organization's annual turnover in [year]? • What is your organization's market share in the business of COs? • How many clients does your organization have in the CO business?

Indicator building	• # subject-related jobs Nature of jobs • # of CO related products/services • Turnover • Market share in the business of Cos • # of clients in CO business and enabling technologies
Availability of data	low
Feasibility	Resource demanding
Comments/caveats	This is part 1 of 4 re. CS supply side
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Economy - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**International trade & investment**
Description	Change in international trade and investment of a company because of involvement in a CS project
Domain	Economy
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project partners, participants
Time-series	Yes, ex-ante/ex-post survey
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Organization
Analytical level (logic model)	Context, input, output, outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Questionnaire that was filled in by project partners twice to collect data about baseline and economic impacts of the COs
Data collection item(s)	• How many international clients does your organization have in the CO business? • What specific customer segments does your organization serve related to COs? • How much has your organization invested in CO-related activities in [year]?
Indicator building	• # of international clients CO business and enabling technologies • Customer segments (sectors) related to CO • Amount of investment in CO-related activities
Availability of data	low
Feasibility	Resource demanding
Comments/caveats	This is part 2 of 4 re. CS supply side
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Economy - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Innovation & research**
Description	Changes in research and innovation because of involvement in a CS project
Domain	Economy
Qual/Quantitative	Quantitative
Primary/Secondary data	Primary data
Source of data	Project partners, participants
Time-series	Yes, ex-ante/ex-post survey
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Organization
Analytical level (logic model)	Context, input, output, outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Questionnaire that was filled in by project partners twice to collect data about baseline and economic impacts of the COs
Data collection item(s)	• How many IPRs related to COs and enabling technologies (patents, trademarks, copyright, other know-how rights) does your organization hold? • How many CO-related research projects is your organization currently involved? • In total, what is your organization's budget (income & own investment) in these CO-related research projects?
Indicator building	• IPR (patents, trademarks, copyright, other know-how rights) • # of CO-related research projects • Total budget of CO-related research projects
Availability of data	low
Feasibility	Resource demanding
Comments/caveats	This is part 3 of 4 re. CS supply side
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Economy - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Competitiveness**
Description	Changes to market competitiveness of a company because of involvement in a CS project
Domain	Economy
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project partners, participants
Time-series	Yes, ex-ante/ex-post survey
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Organization
Analytical level (logic model)	Context, input, output, outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Questionnaire that was filled in by project partners twice to collect data about baseline and economic impacts of the COs
Data collection item(s)	• What value proposition(s) related to COs and enabling technologies does your organization have? • Which market segments does your organization serve? • How many different revenue streams does your organization have for CO-related value propositions? • How many partners for Cos and enabling technologies does your organization have?
Indicator building	• # of revenue streams • # of market segments served • # of CO topic-related partners
Availability of data	low
Feasibility	Resource demanding
Comments/caveats	This is part 4 of 4 re. CS supply side
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Economy - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Employment**
Description	Changes in employment in a company, because of involvement in a CS project
Domain	Economy
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project partners, participants
Time-series	Yes, ex-ante/ex-post survey
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Organization
Analytical level (logic model)	Context, input, output, outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Questionnaire that was filled in by project partners twice to collect data about baseline and economic impacts of the COs
Data collection item(s)	• In your organization, how many jobs are currently directly related to [CO topic]? • What is the nature of these jobs? (junior, medior, senior position(s))
Indicator building	• # subject-related jobs Nature of jobs
Availability of data	low
Feasibility	Resource demanding
Comments/caveats	This is part 1 of 3 re. CS demand side
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Economy - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Conduct of business**
Description	Changes to costs and availability of essential inputs for a company to be able to participate in a CS project
Domain	Economy
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary data
Source of data	Project partners, participants
Time-series	Yes, ex-ante/ex-post survey
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Organization
Analytical level (logic model)	Input, output, outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Questionnaire that was filled in by project partners twice to collect data about baseline and economic impacts of the COs
Data collection item(s)	• Overall, what are the current costs of external inputs (e.g. data, public opinions, expert knowledge) that your organization needs in order to perform its function in relation to [CO topic]? • How easily available are these external inputs (e.g. data, public opinions, expert knowledge)? (example of efforts)
Indicator building	• Cost of essential inputs (e.g. data, opinions, knowledge) • Availability of essential inputs (e.g. data, opinions, knowledge)
Availability of data	low
Feasibility	Resource demanding
Comments/caveats	This is part 2 of 3 re. CS demand side
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Economy - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Value added for organizations**
Description	Value added for a company (in terms of cost avoidance) because of involvement in a CS project
Domain	Economy
Qual/Quantitative	Quantitative
Primary/Secondary data	Primary data
Source of data	Project partners, participants
Time-series	Yes, ex-ante/ex-post survey
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Organization
Analytical level (logic model)	Output, outcome, impact
Links with indicators in other domains	N/A
Data collection method(s)	Questionnaire that was filled in by project partners twice to collect data about baseline and economic impacts of the COs
Data collection item(s)	• For your organization, what is the value added of the citizen observatory focused on [CO topic] for your capital expenditure? (Cost avoidance due to CO - CAPEX) • For your organization, what is the value added of the citizen observatory focused on [CO topic] for your operating expenditure? (Cost avoidance due to CO (OPEX))
Indicator building	• Cost avoidance due to CO (CAPEX/OPEX)
Availability of data	low
Feasibility	Resource demanding
Comments/caveats	This is part 3 of 3 re. CS demand side
Source of indicator definition	Wehn et al. (2017, 2019, 2020)

Economy - Indicators ID	
Indicator Characteristics	
Aggregate indicator name	**Economic potential and market opportunities**
Description	Economic potential that can be exploited in the future; competitive advantage; cooperation for exploitation (e.g. with social entrepreneurs); economic impact, e.g. cost reduction, new job creation, new business model, etc.
Domain	Economy
Qual/Quantitative	Quantitative & qualitative
Primary/Secondary data	Primary and Secondary data
Source of data	Not specified
Time-series	Yes, ex-post and ex-ante
Unit of measurement (observation)	Absolute values & nominal
Unit of analysis	Project
Analytical level (logic model)	Outcome, impact
Links with indicators in other domains	Society
Data collection method(s)	Not specified
Data collection item(s)	• Does the project have any economic potential to be exploited in the future? • Does the project include any competitive advantage? • Does the project have any cooperation for exploitation, e.g. with social entrepreneurs? • Does the project generate any economic impact, e.g. cost reduction, new job creation, new business model, etc.?
Indicator building	Not specified
Availability of data	low
Feasibility	Insufficient information to judge
Comments/caveats	
Source of indicator definition	Kieslinger et al. (2017; 2018)

Annex 11 Example of draft scheme for monitoring long-term impacts of the Outfall Safari case study, UK

		Monitoring scheme				
		Indicator	**Method**	**Frequency**	**Who is involved?**	**Feasibility**
Long-term Impacts	Wider public awareness / changing attitudes of polluting outfalls	Social media interaction(s)	Track social media (e.g. record number of tweets, posts, likes etc.)	Continual	Project coordinators	Feasible
		Interest in project - sign-up for newsletter etc.	Counts of interested people receiving communications	Continual	Project coordinators	Feasible
		Number of people participated in training	Count of new volunteers signing up to be involved	At training events - once a year		
		Change in attitudes / awareness of polluting outfalls	Questionnaire gauging changing public attitude to PSO	Annually	Project coordinators	Unclear
			Retrospective questionnaire for citizen scientists already involved	One off activity	Project coordinators	Feasible
				Annually - to record change over time		
			Questionnaire before and after training for new citizen scientists	Annually - at training event*[9]	Citizen scientists - self reporting	
	Improved river water quality and habitat	Number of misconnections remedied	Water companies communicate number of Outfalls fixed	Annually	Project coordinators	Feasible – already done
				Quarterly		Feasible
		Water Framework Directive (WFD) status of rivers	Monitoring undertaken by other citizen science projects, e.g. Riverfly	Monthly, in the case of Riverfly	Citizen scientists - Riverfly volunteers	Feasible
			Statutory agency monitoring	Unsure	Project coordinators	Feasible
		Outfalls where remediation has taken place remain non-polluting	Outfall Safari surveys	4 years – completion of survey period	Citizen scientists and project coordinators	Feasible
	Improved Policies / Legislation	Institutional change (e.g. Thames Water - changed procedures, policies etc)	Retrospective questionnaires for Water Companies	Yearly	Self-reporting by project coordinators	Feasible
			Literature search	Yearly	Project coordinators	Feasible
		Number of communications to local MPs that have been taken up	Citizen scientists self-report	Yearly	Citizen scientists	Feasible

		Governmental Policy change / written legislation	Policy / legislation search	Yearly	Project coordinators	Feasible