EUROSCITIZEN COST ACTION - WORKING GROUP INFORMAL EDUCATORS (WG3)

PILOT STUDY REPORT

Exploratory study of evolution-themed, non-formal education in Europe

This article/publication is based upon work from COST Action < CA17127 Building on scientific literacy in Evolution towards scientifically responsible Europeans >, supported by COST (European Cooperation in Science and Technology).
www.euroscitizen.eu

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Abstract
This exploratory study aims to describe the learning opportunities in evolution across Europe in non-formal contexts. To better understand the current situation as well as to describe the landscape in evolution-themed, lifelong learning in Europe, we in the Working Group “Informal Educators” of the EU COST Action EuroScitizen have undertaken a literature review in addition to collecting survey responses from non-formal educators and conducting interviews with a selected subset thereof.

Given the complexity of lifelong learning, improving the existing learning experiences outside of the more formal schools and universities as well as developing new and more impactful ones, requires a collaboration between any and all of evolutionary biologists, anthropologists, museum curators, educational researchers, psychologists and pedagogists, among others.

Based on our study we hold that a systematic approach is needed to improve how evolution is presented to the general public and to raise scientific literacy in this area and beyond. This approach will require improved impact assessments of existing and future activities; reconsidering the role that non-formal learning holds in transferring knowledge from cutting-edge research to the general public; and, more generally, reinforcing lifelong learning (beyond mandatory education) to improve the scientific literacy of all European citizens.

Keywords
evolution, scientific literacy, non-formal learning, lifelong learning, assessment

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Introduction

The EU COST Action EuroScitizen is dedicated to investigate the approaches used to improve public scientific literacy in evolution by engaging evolutionary biologists, educational researchers, educators, museum professionals and media professionals. One specific goal of the Action is to explore learning opportunities in evolution across Europe in non-formal contexts. As a first step in this direction, an exploratory survey of such opportunities in Europe was created by Working Group 3 (WG3, “Informal Educators”) of the Action with WG5 (“Scientists”) complementing it by examining the scientific outreach performed by scientists.

WG3 is focused on identifying and examining the best practices in science exhibitions, exhibits and other, “non-formal” educational programmes. The aim thereby is to assess the impact of such non-formal learning environments on the public’s scientific literacy in evolution and, more specifically, to evaluate the effectiveness of European museums and science centres in promoting lifelong learning in evolution in informal settings. Despite the huge potential that natural history museums, botanical gardens and science centres have as environments to promote lifelong learning, their effectiveness in teaching evolution in Europe has received little attention. In the US, studies have shown that teaching evolution in a museum setting can be highly effective and that even a single visit to an evolution exhibition can improve visitors’ understanding of this topic and resolve many misconceptions (Spiegel et al., 2012).

Complementing WG3, WG5 focuses on how to improve efficient researcher engagement in science outreach (which is non-formal by definition) and in evolution in particular. The aim is to provide a sound understanding of those factors that influence a researcher’s engagement in scientific outreach, to increase awareness about the benefits for both researchers and the general public from their interactions and to promote efficient interactions.

Statement of purpose

This report presents an exploratory study of the non-formal learning opportunities in evolution that exist in Europe. Our aim is to describe the current situation and to propose improvements that can guide the design and implementation of future learning opportunities. We hope that this report brings some new insights to all those researchers, science communicators, museum curators and non-formal educators more broadly who seek to understand the best practices in communicating about evolution and to convey the basics of scientific literacy to the general public.

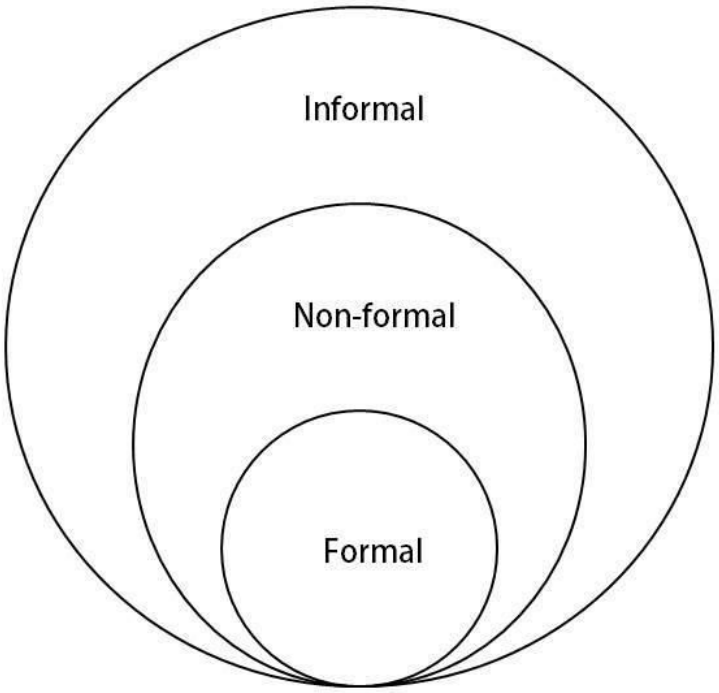
Area and topic

In this report, we are exploring evolution-themed, non-formal activities across Europe. This exploratory study was created to ask whether or not we can recognise and measure the impact of non-formal evolution education on the scientific literacy of the general public.

Background and context

The tripartite conceptualisation of informal, non-formal, and formal learning was proposed most famously by Coombs and Ahmed (1974), likely in response to a call from UNESCO and the World Bank to extend knowledge making with notions of lifelong learning. Since then, the literature summarizes four primary means of categorization for science learning outside of the school: setting, learning process or pedagogical approach, qualifications, and intention. In similarly adopting these categorizations, we would note that although categorization by setting can be useful, it simultaneously can serve to oversimplify the distinctions between learning concepts.

Within this general context, we will adopt the definitions for formal, non-formal, and informal science learning as presented by the National Centre for Vocational Education Research of Australia (NCVER 2013/17) because their universality, and inclusiveness with regard to subjects, levels, and contexts make them functional for a variety of ages, countries, activities, abilities, and topics.



Informal - Learning resulting from daily activities related to work, family or leisure. It is not organized or structured (in terms of objectives, time or learning support). Informal learning in most cases is unintentional from the learner's perspective. It typically does not lead to certification.

Non-formal- Any organized and sustained educational activity that does not correspond exactly to the definition of formal education.
Non-formal education may, therefore, take place both within and outside educational institutions, and cater to persons of all ages.

Formal - Learning that takes place through a structured programme of instruction which is generally recognized by the attainment of a formal qualification or award (for example, a certificate, diploma or degree).

Based on these definitions and in contrast to the official name of WG3, the term “non-formal better describes the area of research of this report and so will be used throughout. Non-formal learning opportunities most often use a dialog-based approach led by a qualified facilitator who is trained to encourage critical thinking, exploration and, most importantly, reflection (Affeldt et al., 2015; Sasson, 2014; Struminger et al., 2018). Dialog-based learning is a pedagogical approach that involves students in the collaborative construction of meaning and is characterized by shared control over the key aspects of learning discourse (Reznitskaya &

Gregory, 2013). It is commonly used with autonomous subject exploration in a non-formal setting to create a mixed method approach to science education (Eshach, 2007; Sezen Vekli, 2013). Non-formal learning does not typically feature assessment, but when they are conducted, they are mostly used to provide insight on the ability of a workshop, exhibition or other activity of intervention to meet institutional objectives, rather than to evaluate the learner (Phipps, 2010). The literature categorizes most non-formal learning experiences as being self-directed (Clapham, 2016; Menezes et al., 2018; Tan, 2018), where the learner exercises a large degree of control over the learning situation, to the point where it is determined and initiated by the learner.

Analyzing non-formal education approaches naturally brings us to evaluate not only the implementation of the activities, but also the objective these activities have in terms of learning and knowledge / skills transfer with respect to evolution. For the latter purpose, we adopt here a flexible nomenclature and use the terms “learning goals / objectives / outcomes” interchangeably, as proxies for analogous terms used in different countries and scientific cultures to describe the intended objective in terms of understanding scientific content, adopting a scientific way of thinking, or acquiring scientific skills.

Research questions

General research question

What is the landscape of non-formal education in evolution across Europe?

By “landscape” we mean to describe the diversity of non-formal education formats, including information about their creators, target audience, presented topics and impact assessment.

Specific research questions

- Which countries participate in non-formal education in evolution?
- Which institutions are involved in delivering non-formal education in evolution?
- Who is usually targeted by non-formal learning activities in evolution?
- How are non-formal learning activities funded and valued in different institutions and countries?
- Which topics in evolution are primarily presented in non-formal learning activities?
- How and why are non-formal learning activities in evolution assessed?
- What is the focus of impact assessments and how are the results used?
- Can we propose a framework to assess the impact of non-formal learning activities in evolution; based on an analysis of published research and on the collective experience of practitioners who have attempted to assess their non-formal learning activities?

Conceptual framework

Because we are investigating a topic for which previous systematic studies do not exist, we have chosen to use the framework of exploratory research (Hox & Boeije, 2005) to understand and define the problem more clearly, to describe the landscape of non-formal learning of evolution is available across Europe (e.g.., what activities are being offered where and how often), and to assess how such learning impacts on the level of scientific literacy in Europe.

In doing so, we have employed both primary and secondary research methods. For the former, we have created an initial survey and conducted interviews to understand the current situation and implementation of non-formal activities across Europe, whereas for the latter we also analysed the existing literature on the assessment of activities addressing evolutionary topics.

Methods and results

Systematic literature review of the assessments carried out in museums and science centres to evaluate the impact of evolution-themed activities

The aim of the review was to provide an overview of evaluations into effectiveness of European museums and science centres in promoting lifelong learning in evolution. This approach provides an assessment of this field of work and will form an important foundation to guide future research in this area.

Strategy and design

Methods used for the literature review

The literature review was designed to answer the research question:

What does the research literature reveal about the assessment and impact of non-formal educational activities in the field of evolutionary biology? The purpose of the review was, therefore, to establish what we know about:

1. the types of non-formal educational activities being assessed / evaluated about evolutionary biology,
2. the goals of these evolutionary biology activities,
3. the assessments that have been conducted to evaluate these activities, and
4. the results of these evaluations.

Sample and sampling

Types of publications included

Given that the research question asks what the 'research' literature reveals, it was decided that only peer-reviewed papers, published in mainstream journals from recognized, *bona fide* publishers were included and none of the so-called "grey" literature (e.g. non-peer reviewed publications, websites, blogs, or newsletters, among others). This decision had the effect of excluding the many "predatory" journals[1] that often publish less qualified work that is not properly or rigorously peer-reviewed.

Language of publication

Only English language publications were included to facilitate the analysis done by reviewers coming from different countries, only sharing English as a common language.

List of 19 included publications

Authors	Year	Title
Spiegel, A., Evans, M., Gram, W., & Diamond, J.	2006	Museum visitors' understanding of evolution
Scott, M., & Giusti, E.	2006	Designing human evolution exhibitions. Insights from exhibitions and audiences
Abraham-Silver, L., & Kisiel, J.	2008	Comparing visitors' conceptions of evolution: examining understanding outside the United States
Evans, E. M., Spiegel, A. N., Gram, W., Frazier, B. N., Tare, M., Thompson, S., & Diamond, J.	2010	A conceptual guide to Natural History Museum visitors' understanding of evolution
Bowler, M. T., Buchanan-Smith, H. M., & Whiten, A.	2012	Assessing public engagement with science in a university Primate Research Centre in a National Zoo.
Falchetti, E. M.	2012	Biological evolution on display: an approach to evolutionary issues through a museum
Pickering, J., Fawcett, L., & Munstermann, L.	2012	An alternative approach: teaching tvolution in a natural history museum through the topic of vector-borne disease
MacFadden, B. J., Oviedo, L. H., Seymour, G. M., & Ellis, S.	2012	Fossil horses, orthogenesis, and communicating evolution in museums

[1] https://beallslist.net/wp-content/uploads/2019/12/criteria-2015.pdf

Torrens, E., & Barahona, A.	2012	Why are some evolutionary trees in natural history museums prone to being misinterpreted?
Spiegel, A. N., Evans, E. M., Frazier, B., Hazel, A., Tare, M., Gram, W., & Diamond, J.	2012	Changing museum visitors' conceptions of evolution
Diamond, J., & Scotchmoor, J.	2013	Exhibiting evolution
Sayer, E. J., Featherstone, H. C., Gosling, W. D., & the BES Roadies	2014	Sex & bugs & rock 'n roll – getting creative about public engagement
Novick, L. R., Pickering, J., MacDonald, T., Diamond, J., Ainsworth, S., Aquino, A. E., Catley, K. M., Dodick, J., Evans, E. M., Matuk, C., Sacco, J., & Scott, M.	2014	Depicting the tree of life in museums: guiding principles from psychological research
Barone, L. M., Petto, A. J., & Campbell, B. C.	2014	Predictors of evolution acceptance in a museum population
Crivellaro, F., & Sperduti, A.	2014	Accepting and understanding evolution in Italy: a case study from a selected public attending a Darwin Day celebration
Çila, E., Maccariob, N., & Yanmaza, D.	2016	Design, implementation and evaluation of innovative science teaching strategies for nonformal learning in a natural history museum
Cotner, S., Mazur, C., Galush, T., & Moore, R.	2017	Teaching the tourists in Galápagos: what do Galápagos National Park guides know, think, and teach tourists about evolution?
Sheffield, S. L., & Bauer, J. E.	2017	Darwin Day in deep time: promoting evolutionary science through paleontology
Hebets, E. A., Welch-Lazoritz, M., Tisdale, P., & Wonch Hill, T.	2018	Eight-legged encounters—arachnids, volunteers, and art help to bridge the gap between informal and formal science learning

Limitations

The literature search and analysis were limited by language and included English language material only, which may show bias towards Anglo-saxon scientific and/or educational culture. Moreover, because only peer-reviewed papers were included, the large number of annual

reports available, predominantly from natural history museums, were, unfortunately necessarily excluded from the analysis.

Each of the 19 papers was assigned to one reviewer, a member of the WG3 group, for analysis.

Data collection - instruments and procedures

Defining the databases

Several databases were used to find suitable published articles (see Table 1) and were chosen according to the following criteria:

- The database contained peer-reviewed articles rather than “grey” literature;
- The database allowed for the complex search strings needed to narrow the resultant ‘hits’ to the most relevant articles;
- The database included science and social-science journals.

The more commonly used search engines, such as Google Scholar, were not included because the results from such searches often deliver “grey” material, books (e.g., books available on Google books) and much more search “noise”. It was also recognised that the pertinent and relevant results from such search engines would be included in the key academic databases.

Table 1. Databases used to find relevant research literature

Database	**URL**
PubMed	https://www.ncbi.nlm.nih.gov/pubmed/
Web of Science	www.webofknowledge.com
Scopus	https://www.scopus.com/search/form.uri?display=basic
Taylor & Francis	https://www.tandfonline.com/
EBSCO	https://www.ebsco.com/academic-libraries

Defining the search strings

Based on the agreed upon research question, a set of search strings was devised through a process of trial and error to best query the databases for the relevant literature through a combination of keywords (e.g., 'outreach', 'public engagement', or 'evolution') linked with Boolean operators (e.g., 'AND', 'NOT', or 'OR'). The groups of keywords used in the search were:

1. evolution, natural selection, microevolution, macroevolution, human evolution, and drift;
2. public engagement and outreach
3. impact, assessment and evaluation
4. exhibitions, festivals, Darwin day, videos, workshop, games, speed dating, and science fair; and
5. non-formal and informal.

Generally, groups of search terms were searched linked either all with AND as well as all with OR. The operator NOT was only used in specific cases to eliminate obviously false hits (e.g., searching for "human evolution" and "natural selection" returned many hits from the area of artificial intelligence or public health). Similarly, groups of search terms were also linked using either AND or OR.

Initial searches suggested that there were many thousands of potential papers contained collectively within the databases. To focus the search on only those articles where the search terms formed an important part of the paper, we required that they appear in the title, abstract or keywords of the publication, but not in the full-text only.

The search was conducted between November 1st and 6th, 2019.

Data analysis

Several predefined questions in the form of a template were set to unify the reviews across reviewers:

- What is the context and type of the activity and of the assessment? (Add a brief description of two lines maximum.)
- What contents were addressed or what learning goals were evaluated? (Includes: content knowledge in evolution, patterns of evolution, processes of evolution, motivation, attitudes, conceptions, scientific practices, scientific skills, effectiveness, acceptance.)
- Who was the audience? (Present some data of gender, age or academic background.)
- How was the data collected? (Observation, survey, other.)
- What data collection instruments were used? (Observation: observation grids, field notes, video recording, audio recording; Survey: questionnaires, interviews, games; Other.)
- How have the instruments / procedures been validated?
- What were the results of the evaluation? Did the impacts match the learning goals? What were the main conclusions / recommendations?
- Is there any mention of how this activity was extended to a wider audience than the initial one?

Results

The following is a summary of the results of the predefined questions.

What is the context and type of the activity and of the assessment?

The majority (12 out of 19) of research papers assessed museum exhibitions from different contexts. One major context was to find the most appropriate ways of presenting evolution (10/19) and specifically the Tree of Life, to achieve a better understanding of it. A second context was how the visitors perceived specific exhibitions and whether or not the expected evolutionary message was conveyed properly (6/19). A minority of papers (4/19) dealt with public engagement and science communication activities outside of museums.

What contents were addressed or what learning goals were evaluated?

The content of the publications included content knowledge in evolution, patterns of evolution, processes of evolution, motivation, attitudes, conceptions, scientific practices, scientific skills, effectiveness, and acceptance of evolution.

In the majority of the reviewed papers (12/19), the dominant focus of the evaluations was the content knowledge of evolution. In several papers, the acceptance of evolution was also assessed (4/19), but this topic was the only focus in just one paper. The learning goals were not evaluated separately, although they were mentioned in several papers.

Who was the audience? (Data on gender, age or academic background)

The “general public” was the most frequently stated audience in the analysed papers (10/16). However, because the majority of papers were assessing museum exhibitions, the sample cannot be assumed to be the same as the general public *per se*. By coming to a museum, regardless of the motivation, museum visitors are arguably more open to learning than the general public, and so possibly do not represent a random sample of the latter. As such, making general conclusions based on their responses might not be easily generalisable to the entire population.

In some papers, the students and teachers were the main audience and, in another case, those two groups were assessed separately from the general public, with new tools that were developed for them in an *ad hoc* manner.

What technique and which instrument of data collection was used, and have they been validated?

(Predefined answers: Observation: observation grids, field notes, video recording, audio recording; Survey: questionnaires, interviews, games; Other)

There was an almost equal distribution among the major categories of data collection techniques (i.e., observation, survey and other) that were used. Standing out among the different approaches, however, was the study of Bowler et al. (2012) in which the movement of individual, focal visitors' through the exhibit was continuously measured, and recording the time spent in each section to designate a series of visitors' zones. Similar to the pattern for the data collection techniques, the instruments used to collect these data were diverse. Some papers used focus groups and interviews, with others using either open or close-ended questionnaires depending on the aim.

Only two of the used instruments/procedures had been validated in the publication they appeared in Spiegel et al. (2012) and Barone et al. (2014).

What were the results of the evaluation? Did the impacts match the learning goals? What were the main conclusions / recommendations?

Because the majority of analysed research papers assessed museum exhibitions from different perspectives, their results and main conclusions focused predominantly on museums and not on outreach more generally. Most recommendations addressed how the evolutionary exhibition should instead be visualised and presented to the public to achieve a higher level of understanding. In some papers, the main conclusion highlights concerns over a lower level of evolutionary understanding among adults, especially in older generations. Some papers emphasised museums as equally important contributors to scientific literacy as the formal educational system, particularly when the methodology behind the science is presented or showcased as an important part of the exhibition.

Was there any mention of how this activity was extended to a wider audience than the initial one?

This topic was not addressed in any of the papers.

Exploratory survey to construct a database to analyse non-formal, evolution-themed activities in Europe

To explore the level of scientific literacy in non-formal educational environments across Europe, we collected data on existing evolution-themed activities in such settings and investigated whether their presenters assessed the impact their activities had in raising the level of scientific literacy. As such, a newly created survey was widely distributed to reach museums, science centres, NGOs, research centres, and all other organisations and individuals with suitable activities not directly linked with formal educational systems.

Strategy and design

The survey was initially developed during the WG3 meeting in Porto, Portugal in February 2019. Because this exploratory survey overlaps with the creation of a repository platform for scientists' outreach activities, we worked with WG5 to include categories and questions that would help them use the same survey to achieve their goal.

Because of the lack of a sufficient number of responses, the survey will be freely available beyond the initial timeplan (June to the end of September 2019) for the duration of the Action to allow as many interested parties to add their non-formal learning activities to it. Nevertheless, we constructed a preliminary database at the beginning of December 2019 and performed a data analysis of it.

The questions in the survey were as follows.

- What type of institution do you work at?
- Does your institution formally value your outreach activities?
- Who are you?
- What is your position?
- What kind of activities did you perform?
- What was the name of the activity?
- Please add an online link to the activity/project if there is one:
- Please add the link of the google map location of your activity/project:
- Was the activity part of the national or school curriculum?
- What was the topic of the activity? Please select as many as applicable.
- Please add any other keywords that might apply to the activity.

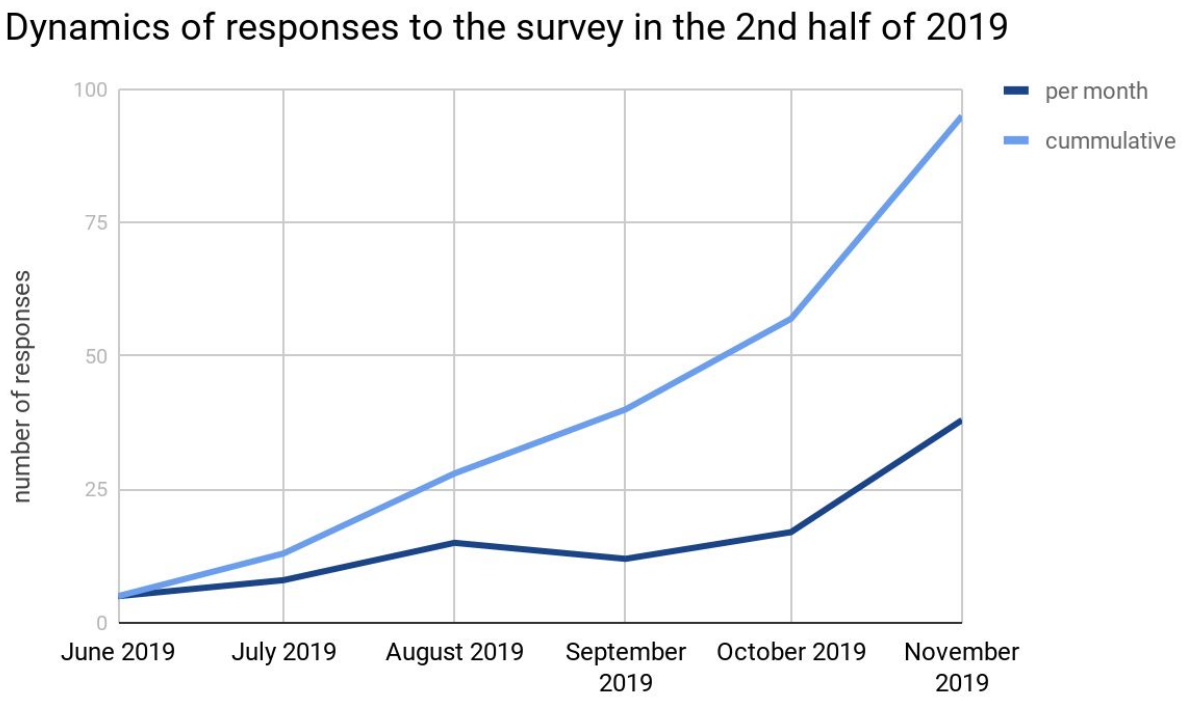
- Who was the targeted audience? Please select as many as applicable.
- What was the planned take-home message/learning outcome?
- When did the activity take place?
- Was the activity per se funded?
- Who funded the activity?
- Did you have an assessment or impact feedback of the activity?
- If yes, was it qualitative, quantitative or both?
- What was assessed?
- If the activity was not assessed, could you please self-assess it?
- If the activity was not assessed, would you be willing to assess it in the future?
- Would you be willing to share the assessment data?
- Would you be willing to share the activity at the publicly accessible repository as a part of EuroScitizen COST Action?
- Was this activity controversial?
- If yes, why do you think it was controversial?

Sample and sampling

The survey was initially distributed within the EuroScitizen COST action and to several professional networks including ECSITE[2], evoldir[3], and EvoKE[4]. In addition, social media in the form of the Facebook and Twitter accounts of both EuroScitizen and EvoKE were also used to announce the survey. Members of EuroScitizen were also asked to forward the survey to their colleagues and personal contacts via email or phone.

Finally, because we had collected less than 60 responses by the end of October 2019, Tamara Milosevic personally contacted more than 50 museums and science centres in 19 European countries by email that were targeted by WG3 members as surely having examples of evolution-themed outreach activities. This approach resulted in an additional 35 responses to the survey.

[2] https://www.ecsite.eu/
[3] http://life.mcmaster.ca/evoldir.html
[4] https://evokeproject.org/



From the outset, we were aware that this survey will not be able to identify non-formal learning activities in all European countries or even to cover all of the many different types of organisations and activities involved. Despite our efforts to include all European countries and to advertise the survey as widely as possible (see above), blanket dissemination was still not possible and two fundamental biases in our distribution are inherent. First, larger institutions were more likely to be contacted, simply because they could be more easily identified by us and were also more likely to have heard about the survey. Second, given that direct contact by members of the Action was a key distribution channel, the institutions that were contacted will tend to reflect the more active members of WG3 and the Action more broadly in terms of country and stakeholder group (e.g., researcher versus (non-formal) educator). For instance, Portugal (31 members), Italy (16), France (14), Poland (13), and Serbia (11) are all strongly represented among the approximately 220 total members of EuroScitizen such that our expectation is that activities in these countries are more likely to have been reported in the survey.

More importantly, despite also targeting specific institutions, the voluntary nature of the survey means that we were unable to control whether or not the relevant authors chose to respond. It is clear that a strong selection exists toward activities where the authors have shown a past tendency to respond to similar surveys, are willing to share information about their work, are comfortable with English, and/or have received the survey announcement at a convenient moment. Interestingly, despite the bias toward larger institutions mentioned above, our feeling is that the most obvious, non-formal educational settings (e.g., museums and science centres) are underrepresented in the survey results compared to other outreach activities (e.g., conferences, workshops, or school activities), perhaps because such institutions regularly undergo analogous self-assessments, thus reducing the motivation to duplicate this effort for an external organization.

Data collection - instruments and procedures

During the creation of the survey, we focused on asking only those questions that were relevant for our objectives. However, some questions regarding the funding of and the formal acknowledgement for creators of the outreach activities were included for the benefit of WG5 to assess the value that different organisations place on outreach.

Our initial analysis of the preliminary data set indicated that most respondents were willing to share the data that they referred to in the survey. For instance, from 92 responses, 76 were willing to share their activity in a publicly accessible repository and 66 who had or were planning to have assessment data were willing to share them as well.

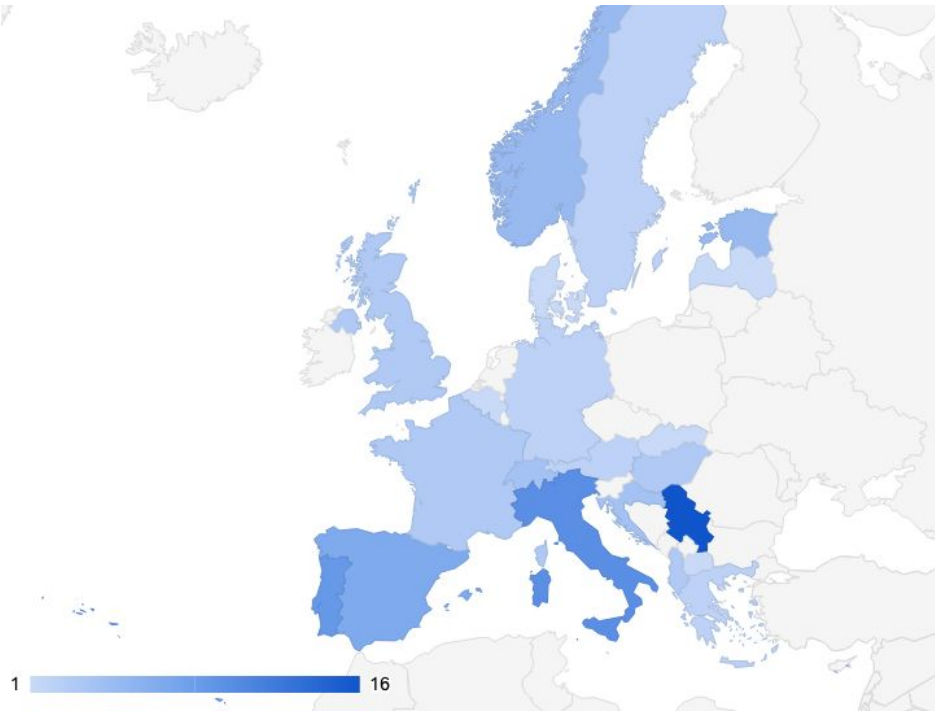
Data analysis

When necessary for statistical reasons, certain categories within multiple-choice questions were pooled. For instance, for the question regarding the respondents´ position in their institution, only three identified themselves as a “museum pedagogist”. We therefore pooled these responses under “educator” to yield the final four categories of “scientific researcher”, “curator”, “educator” and “other”.

Results

The following table and map show the distribution of the 92 valid responses in the preliminary data set. Overall, responses were received from 23 of the 27 member states of the European Union. Most of the respondents were from Serbia, Italy and Portugal, which are well represented in the Action. However, no responses were obtained from Poland and only three from France, despite both countries also being well represented in the network.

Country	# of responses
Albania	3
Austria	2
Belgium	1
Croatia	4
Cyprus	1
Denmark	1
Estonia	5
France	3
Germany	2
Greece	2
Hungary	3
Italy	10
Latvia	1
Macedonia	1
Norway	5
Portugal	9
Serbia	16
Slovakia	1
Spain	7
Sweden	2
Switzerland	4
Turkey	6
United Kingdom	3
Grand Total	**92**



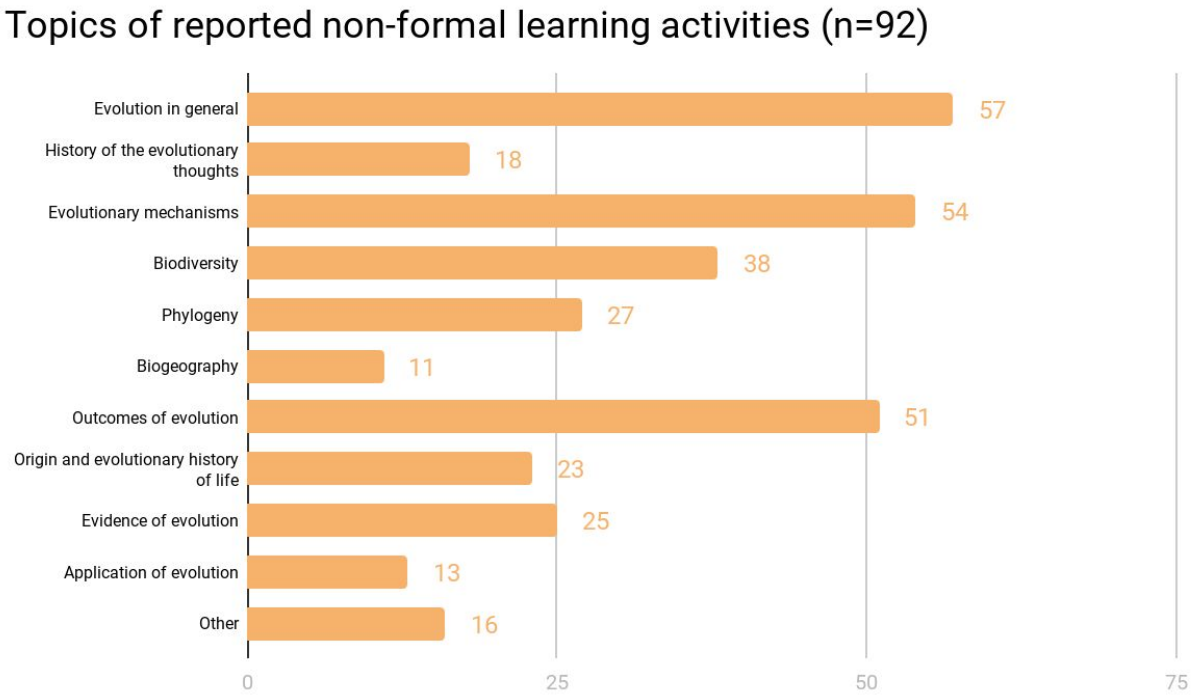
Researchers were by far the most frequent group among the respondents (71). 44 of whom work in universities, 19 in museums and 12 in science centres—thereby perhaps reflecting the potential bias in the canvassing activities of the Actions members, most of whom also identify themselves as researchers. Other respondents work for various NGOs (9), research institutions (2), or other types of institutions (4). Similarly, most respondents defined the position they held in their institutions as “scientific researchers” (44), followed by 21 “educators” (21), 21 “other” (21), and 6 “curators” (6).

Most respondents were directly involved in the activities they described (82), either as creators (41), organizers (36), or both (5). The remaining respondents (10) filled out the survey on behalf of their colleagues. Most respondents were female (46 to 28) and most of the 92 activities were also reported by women (54 to 38). (The discrepancy between the numbers is because a single person could report more than one activity.) However, there was no obvious gender bias in the roles that women and men had in the activities.

Survey questions describing activities

Of the more than 25 different non-formal activity types found in the survey, the most numerous were examples of exhibitions (23), workshops (13), school activities (11), and conference/round table/science cafe (9). However, the survey also uncovered examples of games (4), blogs/websites (3), art and science performances (3), guided visits (3), and citizen-science projects (2). One quarter (23) of the reported activities covered topics that were part of the national or school curriculum, but were offered outside of these formal contexts, mostly categorised either as a school activity (5), workshop (4), conference / round table / science cafe (3), or exhibition (3).

For 69 of the responses, the target audience was mixed and involved one or more of the focal audiences in the survey (e.g., kindergarten, primary schools, or teachers / educators), as indicated on the survey either directly (i.e., the option “mixed general public”, 47 responses) or by selecting two or more of the focal audiences simultaneously (22 responses). The majority of activities addressed evolution in general (57) or the more specific themes of evolutionary mechanisms (54) or the outcomes of evolution (51). Additional, but less frequent topics included biogeography (11), application of evolution (13) and the history of evolutionary thought (18). Most activities were temporary (57) or occurred at regular intervals (18). Only 14 of the activities are permanent. Finally, only eight activities were reported as being potentially controversial. These activities occurred in Turkey (2), Serbia, Hungary, Portugal, Germany, Norway and Belgium.

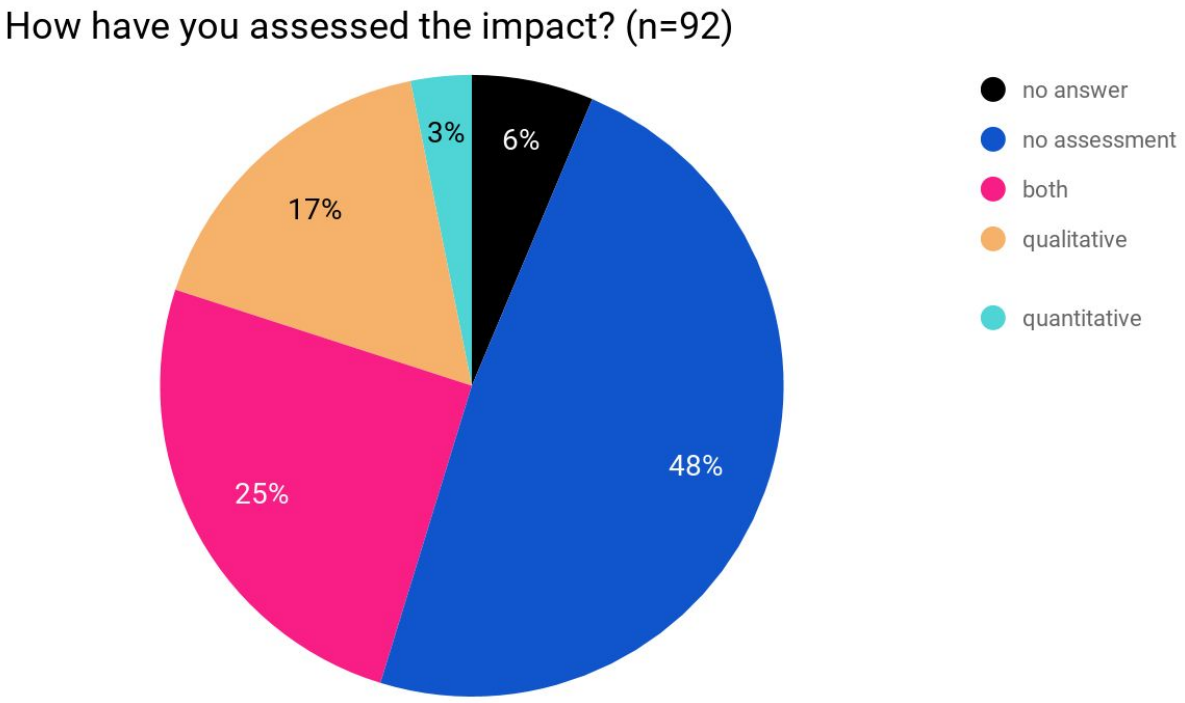


Survey questions linked to WG5 (Scientists): funding and institutional support

Of the 92 responses we received, 79 gave valid answers to those questions about how the institution formally valued the efforts to prepare outreach activities and how these activities were funded (if at all). (One survey did not answer these questions with another 12 stating that they were not applicable in their case.) A total of 61 answers indicated that the effort was formally valued by the host institution. Slightly fewer of these activities (54 of 84) were funded, however, with most funding being external, followed by mixed sources of funding, and finally by internal funding.

Survey questions linked to assessment of impact

More than half of the respondents (50) said they have not done any assessment of their activities or did not answer the question. Of the remaining 42 respondents, most conducted both qualitative and quantitative forms of assessment (25) or qualitative assessment alone (18). A strictly quantitative assessment occurred in only three cases. Unfortunately, there was no information provided as to whether the qualitative assessments were also analysed qualitatively or, as is more often the case, quantitatively.



Of the 42 where assessments were performed, 34 were willing to share the assessment data, 4 were not willing (4 did not reply to this question). Of the 44 who replied they had not had an assessment, 39 replied they would be willing to share - if assessments will be available in the future, while only 4 answered they would not (1 did not reply to this question). 6 did give no reply as to whether they had assessed or not. Those replies are omitted from this section.

83 replied to the question of willingness to share their activity in a publicly accessible repository, irrespective of the activity having been assessed or not. Of the 83, 76 replied they were willing to share the activity, 7 that they were not.

Semi-structured interviews to understand existing strategies in assessing the impact of non-formal evolution-themed activities

Semi-structured interviews were carried out to explore what types of assessments are typically used to evaluate evolution-themed outreach activities, and what those assessments are evaluating. We were specifically interested in those examples evaluating the impact of the outreach activities in terms of improving the understanding of evolution and scientific literacy in evolution in non-formal, educational settings across Europe.

Strategy and design

Building on our exploratory survey, we sought to explore whether evolution-themed outreach activities in non-formal educational settings are contributing to the rise of scientific literacy in evolution. Our aim was to conduct 10 interviews from 10 different countries who were willing to share their assessment data with us and who represented a variety of evolution-themed outreach activities. This selection of examples would represent approximately 10% of the exploratory survey respondents.

Semi-structured interviews (Adams, 2015) were designed with the aim of understanding how and why the evaluations were made. The interview we designed contained nine questions asking about various details about the assessment types and impacts and required a maximum of 30 minutes of the respondents' time.

Sample and sampling

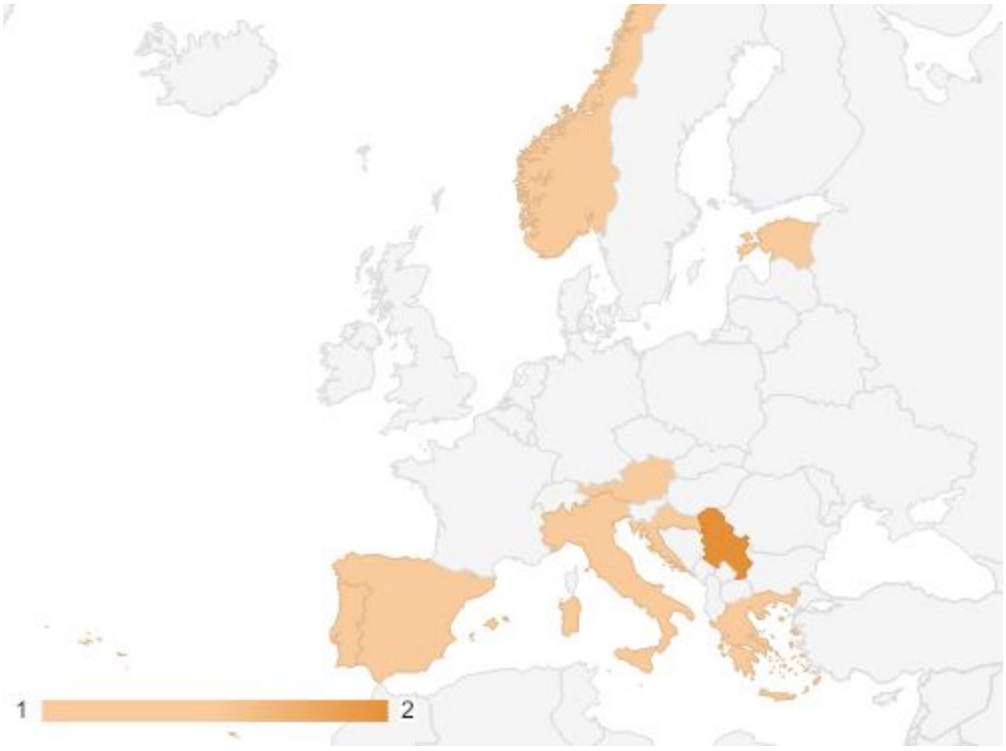
From our exploratory survey, 34 respondents who evaluated their evolution-themed outreach activities were willing to share their assessment data with us:

Country	Number of respondents	Types of activities
Italy	6	teachers' workshop, exhibition, guided museum visits, published popular science articles, conference / round table / science cafe, game
Portugal	5	three school activities, exhibition, workshop
Serbia	4	art and science performance, three exhibitions
Spain	4	video, citizen science, workshop, game
Switzerland	3	exhibition, games and hands-on experiments, and scientific speed-dating event
Austria	2	exhibition and long distance course
Norway	2	several of the school activities, exhibitions, podcasts (other media appearance), publishing popular science etc. reported in one entry, and workshop
UK	2	computer games and citizen science
Croatia	1	workshop
Estonia	1	school activity
Greece	1	guided museum visits
Macedonia	1	popular science articles
Sweden	1	training
Not mentioned	1	school activity

From this pool of 34 candidates, we selected interviews based on the following ranked criteria or desiderata:

1. to have a range of countries across Europe represented;
2. the perceived quality of assessment for those countries with multiple candidates;
3. a selection of different types of activities per country, again for those countries with multiple candidates; and
4. the availability of respondents for interviews.

The final sample included 10 activities from nine of the 13 European countries listed above (Austria, Croatia, Estonia, Greece, Italy, Norway, Portugal, Serbia (2), and Spain) and included outreach activities such as school activities, interactive workshops for different audiences, and museum and botanical garden exhibitions. Activities from Macedonia, Sweden, Switzerland, and the UK were thus not included.



Data collection - instruments and procedures

Interviews were conducted between mid-November 2019 and the beginning of January 2020 by various members of the WG3 either in person, by telephone or via Skype. Except for the Austrian and Spanish interviewees, the interviewers could speak the mother tongue of the interviewees to facilitate the interview being conducted in either English or the mother tongue.

Data analysis

The semi-structured interviews were summarised by the interviewers and, when necessary, translated to English.

Results

What did you evaluate?

The majority of the 10 assessments recorded the number of participants (7), as well as their understanding of the content that the activity presented (6). For the latter, one assessment conducted pre- and post-activity tests to measure the knowledge transfer of the activity. Four of the assessments asked whether the participants liked or disliked the activity or specific parts of it. Additional topics that were evaluated include the participants' engagement in the activity (2), the acceptance of and attitudes toward evolution and science together with a scientific evaluation of the impact of the presentation (1), an indirect estimate the level of general scientific literacy (1), and a public study of visitor conversations during interactions with the exhibition modules (1).

What kind of evaluation / research tools / methods did you use to assess the activity?

The majority of the assessments were conducted using questionnaires with any of open-ended (9), multiple choice (5), and/or Likert-scale questions (4). Two assessments also collected quantitative data to evaluate their respective activities. Additional sources of feedback mentioned in two interviews included gathering comments from visitors' books or information from social media (e.g., Facebook sharing, written feedback, or Google hits). In three cases,

feedback was also sought from the teachers and not only the students attending the activity. For six activities, participants were evaluated for their understanding or retention of the material during or after the activity. Formative assessment during the development of a large exhibition using two focus and three stakeholder groups (teachers, journalists, and citizens) was also mentioned in one interview. A final and more innovative tool was the unique case of the development of an app inspired by a gaming logic that enabled the collection of user data such as GPS / geolocation, usage data for serious games, or concept maps.

What was your motivation to conduct these assessments?

Most of the assessments were initiated by either the creator of the activity (5) or the institution, the entity funding the activity, or local municipality, all with the aim of improving the quality of future (related) activities. In one case, the evaluation also had a pedagogical component in hoping to demonstrate to future teachers how to evaluate the impact of the activity. Finally, one interviewee reported that part of their motivation was to get more inspired for future such activities through the positive feedback they received.

How did you develop the assessment methodology tools?

The assessments were developed by either experts (5), the responsible municipalities (2), or by the creators of the activities (2, and 1 with no clear answer but that seemingly falls into this category). In the latter case, the assessments were designed either by trial and error or by simply using graphic representation to illustrate whether or not the participants understood the concepts being presented. For both self-developed assessments, the design was based on what the creators were interested to find out from the participants, including what was most interesting to them, their satisfaction, what they particularly liked or disliked, or what they understood or retained from the activities.

What type of data did you obtain?

All assessments retrieved qualitative data, with eight using them in combination with quantitative data such as the number and age of the participants as well as how they graded the activity. In at least three cases, the assessments were also adjusted for different age groups or audiences.

How did you use the results of these assessments?

The assessments served two key functions. The first was to understand the impact of the activity (3), possibly with a view to improving similar, future activities (7). A second function was more administrative, with the assessments being necessary for (internal) institutional reports (5) or to justify budget spending to the funders of the activity as well as to apply for future funding (2). In a final case, one interviewee reported using assessment data for advertising the exhibition, as well as for developing it further.

How would you improve your assessment tools?

Of the two interviewees that used the assessment tools made by their municipalities, one stated the municipality improves the tools yearly, whereas the other suggested getting additional feedback from teachers. Other suggestions revolved around the construction of the assessments themselves, with three interviewees stressing the importance of simple assessments that focus on a few, key questions or that use smiley/non-smiley face feedback for each activity to provide quick, qualitative feedback on user satisfaction. Two also stressed the usefulness of multiple-choice questions in this context. An additional consideration mentioned in one case is the importance of designing the assessment tool according to target audience (e.g., age group). However, one interviewee questioned the quality of the feedback data in cases when the feedback is required (see below). More broadly, one of the interviewees was interested in incorporating the long-term retention of knowledge in the future. Finally, another interviewee added that gathering assessment data following the completion of the exhibition design to match those gathered during its initial and ongoing development would be useful.

What obstacles did you encounter when setting up these assessments (or other assessments that couldn't be set up)?

Only three of the 10 interviewees claimed that they encountered no obstacles, with the problems reported by the remainder revolving more around the implementation of the assessments and general logistics. For instance, two people remarked that the age of the students influenced the feedback they provided. Perhaps counterintuitively, small children were often reported to be more reliable respondents than the older ones and trust in the respondents' feedback was raised, especially in the case of teenagers. Again, these examples stress the general importance of age-tailored assessment tools, perhaps also as a means to motivate participants to provide constructive feedback. This is particularly relevant given that most activities were directed at mixed audiences (see above), resulting in variable participant profiles. One recognised the general reluctance of participants to fill out the assessment, especially if it was long or otherwise somewhat tedious. Other problematic issues that were mentioned included the limited access to participants, limited human and financial resources to perform the evaluation, and lack of experience in implementing assessments.

What advice would you give to someone who would like to start assessing their activities?

Two of the interviewees stressed the importance of expert help when designing the assessment tools. Two others emphasized the importance of keeping the assessment simple and with easy-to-answer questions, and another advised collecting the assessments shortly after the activity. One interviewee pointed out the importance of having a clear goal and objectives of the activity and using these to ask specific questions, and another what is to be assessed and for what purposes. One interviewee had very specific advice for the assessment procedures in botanical gardens or similar settings. One interviewee suggested starting the assessment at the beginning of the activity ("formative assessment") and engaging diverse stakeholders in the planning phases of the activity ("co-creation").

The small sample size combined with the diversity of countries, activities, and answers exclude a proper comparative analysis of our data. Clear cultural differences and different "starting

points" were noticeable in different countries or areas. For example, for the activities selected here from Sweden and Estonia, assessments are mandatory and were standardized by the municipality (although it is not clear whether or not this holds for these two countries generally). As such, we are mostly limited to drawing some general conclusions based on some of the tendencies we have observed among the outlined examples.

Apart from administrative necessity, a clear and desirable motivation to gather the assessment data was to use them to **guide improvement** of any future, related activities, in part by evaluating **satisfaction of the participants** with the activity. Key points regarding the form of the assessment were the **importance of its simplicity and relevance** while collecting both **qualitative and quantitative data** using some kind of questionnaire. Altogether, the best strategy was held to be the combination of **multiple-choice questions and interviews**, with the assessment being adjusted to account for **age-dependent understanding of content** and also **age-dependent evaluation of the impact** of the activity. When designing the assessment tool, the **need for expert assistance** was recognized in most cases. Finally, although all but one activity assessed the participants' understanding of the concepts presented during the activity, assessing for the **long-term retention of this knowledge or these concepts** and the **goal of scientific literacy** was only mentioned in one case each.

Outcomes of the exploratory study

This exploratory study of non-formal, evolution-themed activities offers a first glimpse at the major aspects of this approach to learn about evolution in Europe and reveals some open questions that require further investigation. Direct, major outcomes of our study include an interactive map of non-formal learning activities in Europe, a description of the landscape of those activities across Europe, and the major findings regarding the impact assessment.

Interactive map of non-formal learning activities in evolution in Europe

As one of the basic outcomes of our exploratory survey, we have constructed an interactive map to visualize the locations of non-formal learning opportunities in evolution across Europe. The map can be searched by the target audience and/or the evolutionary topic and aims to showcase as many institutions and alternative places of learning (i.e., outside of schools and universities) where citizens can come into contact with evolutionary topics and educate themselves through a diversity of activities adapted for every level. As such, the map can serve to promote non-formal, lifelong learning in evolution by helping citizens explore this subject by visiting permanent and temporary exhibitions, engaging in citizen-science projects, participating in workshops or attending outreach events both at home or abroad.

The map is accessible online[5] and will be updated periodically as new information becomes available to us. Anyone wishing to add non-formal learning opportunities to the map is encouraged to submit their activities using our online form[6].

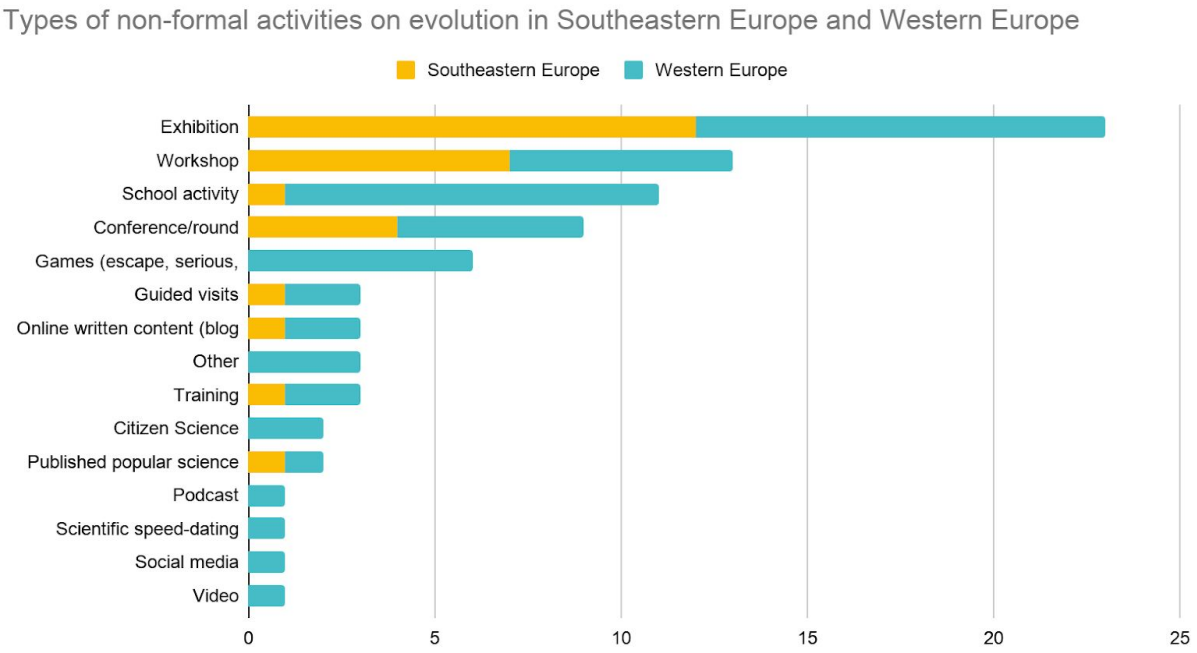
[5] https://drive.google.com/open?id=10YM6-yWizq0DwI1Xt3AYNBmEOYcluZ5g&usp=sharing
[6] http://bit.ly/WG3survey

Landscape of non-formal learning of evolution in Europe

Although our database of 92 activities does not cover anywhere close to all existing opportunities to learn about evolution outside of the formal education system in Europe, it nevertheless paints a diverse landscape despite its incompleteness (i.e., 25 different activity types in 23 countries). Whereas it is safe to say that non-formal learning activities in evolution are performed all across Europe (with the possible exception of eastern Europe), the potential

sampling biases mentioned above do not enable us at present to estimate how equally distributed they are among the different countries.

Nevertheless, a noticeable difference between specific types of activities exists between western vs southeastern Europe (15 vs 8 reported activity types, respectively). Certain novel trends in science outreach (e.g., games, citizen science projects, podcasts, videos, social media and scientific speed-dating events) were not reported in southeastern European countries, where more traditional, "static" ways of presenting science to the public (e.g., 12 cases of exhibitions) predominated.



Moreover, the activities are being carried out by a host of different individuals and organisations, including researchers from research institutions and universities, but also involving museums, botanical gardens, and science centres as well as NGOs, schools and independent educators. In science centres and NGOs, the formal role of which is, in part, to raise the level of scientific literacy of the general public, non-formal education efforts are understandably valued to the

greatest degree among all institutions where such education occurs. However, like for most educational institutions, the difficulty in finding sufficient funding means that the non-formal education facilitated by such institutions might not be receiving sufficient support to fulfill their goals.

Comparatively few activities were designed for specific target groups, but instead attracted a mixed general audience. Although this broadens the scope and impact of the outreach, awareness of the need for age-dependent content to present scientific concepts to different age groups in the most appropriate manner could be prudent in some cases.

Most activities were also not permanent, meaning that the general public might not have access to engaging content on evolution at all times, apart perhaps from permanent exhibitions in some institutions like natural history museums. A lack of funding undoubtedly plays some role here. However, many activities like speed dating or external activities for school classes are transient by design and can also be repeated at regular intervals. By contrast, non-permanent activities, as special events, can function to attract more visitors and therefore can have an increased impact. For example, museums use special exhibitions precisely to draw in new visitors and entice old ones back. Evolution also remains a dynamic research area that is arguably not well suited to permanent displays because the information presented might age relatively rapidly. Although mechanisms and outcomes of evolution comprise the content of most activities in our database, it might be desirable to also pay more attention to less treated subjects including biogeography, the application of evolution to our everyday lives, and the history of evolutionary thought. These subjects might actually help serve to motivate the mixed general audience these activities tend to attract and who might be interested in the historical aspects and understanding of the process of science as well as in the examples of evolutionary processes relevant in our everyday lives.

The survey has also captured instances where the respondents reported the activities as being controversial. Some of these instances might be expected in countries where reoccuring anti-evolution events take place (e.g., Turkey, Serbia and Hungary, as reported by members of the Action). However, there are also several additional examples of reported “controversial”

activities from western European countries where evolution forms part of the school curriculum and is generally regarded to be uncontroversial (e.g., Portugal, Germany, Belgium, and Norway).

Existing impact assessments of non-formal education in evolution

The final research questions in our exploratory study deal with impact assessments of non-formal learning about evolution. Most of our survey respondents did not assess their activities despite the crucial role assessment plays in determining whether or not these activities are raising the level of scientific literacy in Europe. Moreover, if the data from our semi-structured interviews are representative (40% validation rate), then most of these few assessments are not explicitly validated either. However, the interviews also revealed that for those activities that were assessed, the data collected included the number of participants, their satisfaction with the activity, and, in most of the cases, their knowledge and understanding of the topic presented after experiencing the activity. These data tend to match those gleaned from our literature review that suggest that the majority of the 19 articles analysed assess how museum exhibitions present evolution visually and test the visitors' understanding of evolution after visiting these exhibitions.

Through the interviews, the respondents also described some very useful first-hand experience and advice that might otherwise have not been reported. These include suggestions such as involving experts in constructing the assessment, integrating assessment data into the activity, proposing age-dependent assessments and long-term assessments of impact, and the importance of keeping the assessment as simple as possible.

Potential reasons for the lack of assessment in non-formal learning environments treating evolutionary topics

Numerous potential reasons exist why assessments were only rarely performed among the activities in our data set. However, because this question was not addressed on our questionnaire, our inferences (drawn in part from the narratives of the respondents) more properly represent hypotheses that can be tested in the future.

One root cause might originate from the nature of science and the scientific culture that exist in the research institutions (e.g., universities and research institutes, among others) where the majority of our respondents work and we assume are researchers in natural sciences. Because scientific methodology in the natural sciences relies strongly on testing hypotheses quantitatively, natural scientists might not be inclined or simply lack the training to create assessment tools using the appropriate, largely qualitative methodology from the social sciences. This explanation might apply especially in those cases where there is less relevant institutional support (e.g., museums). In addition, because many researchers are probably doing the outreach activities in their “free time”, not only a lack of experience, but also of time might be preventing them from designing appropriate assessment tools that would provide useful information on the quality of their activity.

A clear solution in this case derives from the interviews where the respondents emphasised the need to involve experts in constructing assessment tools rather than trying to design them themselves. However, even with this clear need and appreciation of the role experts can play here, the general lack of funding that exists for evolution-themed activities (or outreach activities in general) limits the degree to which institutions will be willing or able to reach out to experts for developing assessment tools.

Conclusions

Our exploratory study of evolution-themed, non-formal education in Europe has revealed important, major trends in this area as well as hinting at the need to bridge the gap between the natural and social sciences to create meaningful assessment tools. Together, these results can help to guide the development of non-formal learning activities with a higher impact on understanding evolution and a greater contribution to scientific literacy of the general European public.

Lifelong learning in evolution and increasing scientific literacy are topics that necessarily encompass multiple research domains and so inherently demand an interdisciplinary approach. Improving the existing learning experiences outside of schools and universities, as well as developing new and more impactful ones, requires a collaboration between evolutionary biologists, anthropologists, museum curators, educational researchers, psychologists and pedagogists, among others.

Therefore, to improve how evolution is presented to the general public and to raise scientific literacy in evolution, a systematic approach is needed that will require improved impact assessments of existing and future activities; reconsidering the role that non-formal learning holds transferring knowledge from cutting-edge research to the general public; and, more generally, reinforcing lifelong learning (beyond mandatory education) to improve the scientific literacy for all European citizens.

The need for a well structured, validated assessment to evaluate the impact of non-formal learning activities in evolution

Our literature review, exploratory survey and semi-structured interviews provided insight into ways that assessments of non-formal outreach activities can be improved. In particular, there currently is a deficit in terms of measuring the impact of evolution-themed outreach activities and their contribution to scientific literacy in evolution in particular. To measure this impact,

future assessments would need to go beyond current standards that largely measure the popularity of (i.e., number of participants) and satisfaction with an activity and include questions on understanding and accepting evolution. It seems especially important to focus on how scientific literacy can also be assessed, given that this topic was only mentioned in one case during our investigations. However, the latter problem is exceptionally challenging and would require a long-term assessment of any learning rather than the more typical short-term measurements.

In terms of increasing the understanding of evolution in the general public, it is important to highlight those exhibits or examples that most clearly present evolutionary processes and concepts with respect to the target audience. A key aspect of the latter is taking care to adapt the content to the age of the public and to their level of understanding.

Our respondents recommend that the assessments form an integral part of the activity, rather than being conducted only after the activity. They also recommend assessing different parts/topics of the activities independently, and, when appropriate, doing so frequently to assess the overall understanding of major concepts.

Evaluating evolution understanding over the long term and knowledge retention are relevant when measuring scientific literacy in evolution. Long-term knowledge retention is more likely when participants are actively involved in the activity. As such, non-formal educational activities potentially represent excellent tools for long-term retention and promoting scientific literacy. Again, however, the long-term assessment of acquired scientific knowledge and scientific literacy is particularly difficult to perform, not least because of the difficulty of tracking the participants in such a study. Nevertheless, it is possible to envision such assessments occuring in specific settings, like elderly housing and schools, where the population of participants can easily be reassembled after a suitable period of time.

Summary of recommendations when assessing the impact of evolution-themed, non-formal learning activities

1. Make the assessment simple and, if possible, integrate it within the activity;
2. If relevant, adapt the content of the activity and assessment to different age groups;
3. Consider a multidimensional assessment that includes user satisfaction, understanding of evolutionary concepts, acceptance of evolution, and scientific literacy;
4. Focus on collecting qualitative data;
5. When possible, plan for long-term assessments of the impact of the activity.

An exceptional aspect of non-formal education and lifelong learning for the acceptance of science and evolution and increasing scientific literacy

Emotions seem to be central to decision making and also to learning and memory. A key feature of profound empathy in teaching and learning is the development of positive emotions and interactions which create the ambience for learning which enables and fosters open communication (Cooper, 2002). Large classes, lack of time, and the classroom environment created by competition and testing, but also the rigidity of the curriculum, impact on the quality of empathy available in the classroom. Less rigid and more diverse non-formal education system allows more emotional context promoting the process of learning.

There are many ways how we learn (many times unconsciously), but in combination with 'self-direction', non-formal learning must be intentional. Intentional implies that our activities related to learning are somewhat planned and preceded by deliberate goal setting (Moore, 1986). Bandura (1982) described self-efficacy as the most pervasive mechanism driving people's agency. Intention of going to an institution such as a science center and museum can be seen as one of that kind. Also, non-formal experiences were seen as more suitable to provide immersive experiences that offered a "powerful way of tapping into people's emotions" or more simply were just "fun" (Falk et al. 2012). In past decades, science museums and

science centers challenged conventional phenomenon-based installations and created different learning and meaning-making experiences for visitors. Pedretti (2004) discussed that science centers are beginning to see themselves as important players in a number of external scientific, social, cultural, and political contexts quotting: “The science center’s role is to seek tools to draw the cultural framework, animate the debate, and promote healthy skepticism over superstition and irrational thinking” (Beetlestone et al., 1998, p. 21).

That is why it is especially important to assess the contribution of non-formal education to the acceptance and understanding of evolution and to the understanding of nature of science / scientific literacy.

To establish the contribution of non-formal educational activities toward raising the level of scientific literacy, it is necessary to establish ways to measure the impact of such educational activities. Some publications already explore scientific literacy in evolutionary topics, which quick Scopus or PubMed searches revealed. However, because we did not include scientific literacy and evolution as part of our search strings for our literature review, we are not including these publications in our discussion here. Instead, we will review publications on scientific literacy in evolution in the future.

Within the EuroScitizen COST action, our working group with its focus on non-formal education strongly believes that **non-formal learning institutions** (e.g., museums, botanical gardens, and science centers) in concert with **non-formal learning communities** (e.g., citizen scientists, DIY bio communities, and associations of teachers, parents and students) play a key role in **promoting the understanding and acceptance of evolutionary concepts** and hold a great potential to **increase the scientific literacy of all citizens** through lifelong learning opportunities. Our future work will consist of helping these institutions and communities create new activities and to provide them with tools to assess their impact on raising scientific literacy through increased understanding of evolutionary concepts.

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