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THE PEDAGOGICAL SAILBOAT PROJECT

A competence based approach for designing and running citizen science training

I. Addressed challenge

The primary challenge in citizen science projects (CS projects), is to produce reliable knowledge from data collected by non-professional scientists[1]. According to an article in science published in 2014, citizen science practice is not universally accepted as a valid method of scientific investigation, and scientific papers presenting volunteer-collected data sometimes have trouble getting reviewed[2]. Caitlin McDonough MacKenzie et al. mention again that the CS data quality is often called into question[3]. Eréndira Aceves-Bueno et al.[4] mentioned, in 2017, that lesser than two-thirds of citizen science data quality analyses "show accuracy levels that meet our minimum thresholds for accuracy in scientific research". Even if the applied methodologies to reach this last conclusion had some limitation according to Hannah Specht et al.[5], the issue is pending, and more investigation is needed to define the accuracy of CS data.

The citizen science designers generally include different methods to tackle this issue[6][7]. One of these methods is the development of training sessions to obtain meaningful outcomes from the participants.

II. The training in CS projects

The term "training" refers here to the action of teaching skills and knowledge in order to develop a competence related to a specific task/activity in the frame of a CS project. The training goals are generally related to the scientific process that generates new knowledge. However, the training can also be combined with educational and/or societal goals.

III. Who Implementats/executes training in CS projects

CS projects involve three types of trainings :

- Online training:
  In citizen science projects, training is not always carried out by a physical person. CS training designers can use a tutorial in one or more types of support (text, images, games, and video). This type of projects usually involves a very large amount of volunteers and are called "online citizen science".
- Training performed by scientists:
  In CS projects, the scientist might be the person who conducts the training.
- Training performed by scientists:

[1] Law, E. et al. "Crowdsourcing as a tool for research: implications of uncertainty." (2017) P1544–1561 in Proceedings of the 2017 ACM. doi.org/10.1145/2998181.2998197
Google Scholar
[2] Rick Bonney et Al. Science 2014. Vol. 343, Issue 6178, pp. 1436-1437. DOI: 10.1126/science.1251554
[3] Caitlin McDonough MacKenzie et al. "Lessons from citizen science: Assessing volunteer-collected plant phenology data with Mountain Watch" (2017) Biological Conservation, 208, 121-126. doi.org/doi:10.1016/j.biocon.2016.07.027
[4] Aceves-Bueno et al. "The accuracy of citizen science data: a quantitative review." (2017) *Bulletin of the Ecological Society of America* Vol. 98 pp278–290.
[5] Hannah Specht et al. "Biased Assumptions and Oversimplifications in Evaluations of Citizen Science Data Quality" 2018 Bulletin of the Ecological Society of America Vol. 99, pp-256
[6] Margaret Kosmala et Al : "Assessing data quality in citizen science". Brooke (2016) Frontiers in Ecology and the Environment, 14 (10). pp. 551-560. ISSN 1540-9295.
[7] Amy Freitag et al. "Strategies Employed by Citizen Science Programs to Increase the Credibility of Their Data" (2016) Citizen Science: Theory and Practice, 1(1): 2, pp. 1–11, DOI: http://dx.doi.org/10.5334/cstp.6

The organisation of training is time-consuming and not all scientists are available to prepare the training session, gather material, decide on a learning technique, conduct it and evaluate the trainees. In this case, educators from non-formal or formal education (teachers) are involved. The main advantage is not only time saving but also the fact that both educators and teachers are more competent to achieve a training session. They should, however, be trained themselves.

To address the challenges stated above the training designer should identify valid learning methods that allow measuring the learning outcomes[8]. However, as highlighted by Tina Phillips et al[9] "*a majority of citizen-science projects developed to date have conducted less than rigorous evaluations or neglected evaluation altogether.*"
Rachel Becker-Klein et al[10] proposed the embedded assessment method as an effective CS training method "*to capture participant skill gains, and encourage citizen science leaders, evaluators, and researchers to develop authentic methods that address the complexities of measuring skill development*". This method assess participant progress and performance that are integrated into instructional materials. This method is very similar to the competence approach described below as the participants demonstrate their science competencies through tasks integrated within the training.

IV. The competence approach in the learning process

A competence is the ability to accomplish a particular activity to a prescribed standard exploiting appropriate skills, knowledge and attitudes. In Europe, competence-based learning is increasingly used in both non-formal and formal training/education. The competence approach allow the trainee/student to act and perform to set standards of ability and expertise[11].

- Competence-based approach in formal education
  This relatively new conceptual framework is recommended by EC and even mandatory in some countries in the frame of formal education.

- Competence-based approach in non-formal education
  In the non-formal education sector the competence-based approach is applied when rigor is an important requirement (for instance, when the activities imply safety issues). The main motivation is that while a skill is the ability to perform a task, a competence is the ability to perform the task effectively and successfully (master a skill).

V. Why should the designers and conductors of CS training focus on competences?

[8] Becker-Klein, R. et al. "Embedded Assessment as an Essential Method for Understanding Public Engagement in Citizen Science." (2016) Citizen Science: Theory and Practice, 1(1), p.8. DOI: http://doi.org/10.5334/cstp.15
[9] Tina Phillips et al "user's guide for evaluating learning outcomes from citizen science" (2014) Ithaca, NY: Cornell Lab of Orinthology.
[10] Rachel Becker-Klein et al. " Embedded assessment as an essential method for understanding public engagement in citizen science." 2016 Citizen Science: Theory and Practice, doi.org/10.5334/sctp.15
[11] Neil O'Sullivan "Teaching and learning in competency-based education" (2014) 5th conference on e-learning

The requirements for rigor are demanding to ensure effective use of the outcomes of CS projects, however, as highlighted by Maggie Gaddis[12] who investigates citizen science training within her PhD thesis, the main issue remain "*the absence of educational training measurement in citizen science program design and analysis with which to ascertain the learning gains of trained citizen scientists"*.

The competence approach is a valuable method to design and conduct **effective** and **consistent** citizen science training and fill the gaps mentioned above. Let's provide four reasons:

1. The competence approach is a state-of-the-art training method that is aligned to explicit, measurable and transferable learning objectives and outcomes[13];

2. the competence approach focuses on skill mastery not knowledge acquisition. According to PISA (Programme for International Student Assessment), competence is more than just knowledge and skills. It involves the ability to meet complex demands, by drawing upon and mobilising psychosocial resources (including skills and attitudes) in a particular context[14]. In other words this approach answers to the question "How well must it be done?";

3. it eases the possibility of delivering a certificate recognising the level of competence. This might be useful for the re-engagement of participants to new CS projects.

4. furthermore, the competence approach offers future potential for a harmonization of the citizen science training.

VI. Competence mapping for the design and run of CS training

By choosing the competence-based training, both the designer and the educator have at their disposal significant support to carry out their missions: The competence map.

The competence mapping is a process through which the designer identifies and describes the competencies and their most crucial content by defining six important dimensions[15] :

1. The context: The relationship between the competence and the task to be performed.
2. The elements: The breakdown of the competence into several parts (knowledge, skills and attitudes)
3. The levels : The subdivision of the competence in required levels. In table 1, the competence map includes three levels: starting level, advanced level, and experienced level (the column is filled with a rule of thumb as the required level of competence depends on the specificity of each citizen science project).
4. The relationships : The definition of the relationship (when it exists) between the different competences.

[12] M. Gaddis "Training citizen scientists: A qualitative, comparative, multiple case study to identify theoretical and instructional design themes in current citizen science training initiatives" Sigma Xi Student Research Showcase. Available at citsci.org/CitSciBlog/853/Training%20Materials%20Needed
[13] Allen, C., Competencies (Measurable Characteristics), Recommendation of the HR- XML consortium, (2001). http://xml.coverpages.org/HR-XML-Competencies-1_0.pdf
[14] The definition and selection of key competencies : www.oecd.org/pisa/35070367.pdf
[15] Stoof et Al "Web-based support for constructing competence maps: design and formative evaluation." (2007). Educational Technology Research and Development, 55 (4)

5. The outputs: The description of the outcomes, for instance, behaviour, a decision to take etc.
6. The types of competences: In the case of Citizen science we have three types of competences: scientific/technical competences, learning competences, and societal competences (e.g. awareness)

A competence map is above all a tool that allows both the designer and the conductor of the training to visualise at a glance all the critical parameters influencing the outcomes of the training as shown in the generic competence map drawn in table 1. Two of these parameters are described more in-depth below:

1. <u>The phase of the CS research process where the training is needed</u>

The research process is a common element across all CS projects[16]. This process is explicitly described in a competence map (first column of table1). The training designer can identify in which phase of this process the training should occur and what are the needed skills and knowledge to perform the activities.
Bonney et al.[17] defined the key research process steps typically followed by citizen-science programs as follows.

- Defining research questions
- Gathering teams/resources/partners
- Designing data collection methodologies
- Collecting data
- Analysing and interpreting data
- Disseminating results
- Evaluating program success and participant impacts

Until recently, citizen science projects used to be contributory. In this type of projects, the design, the project planning and the analysis of the results are performed by professional scientists. The main activity of the participants is in the so-called "collecting data" phase, and the training is designed to allow the participants to follow specific scientific protocols. Bonney et al. define two other CS types: collaborative projects and co-created projects. Collaborative projects are generally designed by scientists, and the participants contribute to data collection but also may help to refine project design, analyse data, or disseminate findings.
In a paper identifying the future of citizen science project Newman et al.[18] states that "*Wireless sensor networks may connect the laboratory to the natural environment, shifting the focus from elite science to a reality where data collection, analysis, and interpretation are performed by everyday citizens going about their daily lives in partnership with professional scientists*"

Nowadays, co-created CS projects allows participants contributing to problem definition, data collection and data analysis. The design of the training is then relatively more complex as it might occur in all the phases of the Citizen science research project.

Hereafter are two examples of co-created CS projects funded by the European Union

[16] Jennifer L. Shirk et al. "Public Participation in Scientific Research: a Framework for Deliberate Design" Ecology and Society 17(2): 29. dx.doi.org/10.5751/ES-04705-170229
[17] Bonney R et al. 2009. Public participation in scientific research: defining the field and assessing its potential for informal science education. A CAISE inquiry group report. CAISE
[18] G. Newman et Al. "The future of citizen science: emerging technologies and shifting paradigms" , Frontiers in Ecology and the Environment, 2012 - doi.org/10.1890/110294

- Making Sense EU project[19]: This project empowered citizens to discuss methodologies, devise data collection strategies for measuring air pollution, water quality or sound pollution, and interpret the results.
- The pedagogical sailboat project[20]: One of the objectives is to design a competence framework related to citizen science projects realised onboard a sailboat and based on the secondary education curricula. A specific theme was chosen in the project for the validation of the methodology: the sampling of microplastics on the sea surface. This project has the particularity to be coordinated by an NGO.

2. The category of participants who can join the training

The participants of citizen science training come from a variety of disciplines and backgrounds. It is essential to identify, when possible, the already existing competences of the participants.
The competence map provides the minimum necessary competences to join to a task. Depending on the research process phase, the designer should take sensible decisions on which type of participant can acquire the required competences in the slot of time allocated to the training. On the other side, the competence-based approach allows the participant to skip parts of the training if he can demonstrate mastery.

The participants can be divided into the following categories

- Participants without competences (concerned citizens)
- Amateurs with a certain degree of competence in the field
- Students from the formal education systems
- Scientists from other fields

VII. Conclusion

The production of reliable knowledge is the main challenge of CS project. This issue is becoming more crucial as more collaborative and co-created projects (in which the participant should develop skills related to all the scientific process) are created[21]. The quality of the CS project outcomes is directly associated to the participant ability to perform his tasks in the appropriate way. CS community need training methods that include explicit parameters for the evaluation of the participant ability to meet learning objectives and outcomes. The competence approach is a state of the art method that provides this option. Table 1 is a general competence map designed as a template for the designers and conductors of training within CS projects. The competence map can (should) be adapted and extended to the specificities of each CS project. Even if the training does not occur in all the phases, the competence map remains useful as the outcomes of the different competences are connected.

VIII. Acknowledgement

This document includes feedback from the participants of the workshop “Systematic review on training requirements and recommendations”.

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[19] making-sense.eu
[20] thepedagogicalsailboat.eu
[21] Rachel Becker-Klein et al. ” Embedded assessment as an essential method for understanding public engagement in citizen science.” 2016 Citizen Science: Theory and Practice, doi.org/10.5334/sctp.15

Table 1 Competence map for citizen science training

Typical CS Research process steps *(Newman et Al)*	COMPETENCE: TASK DESCRIPTION	Remarks - Explanations- Highlights	Needed knowledge & skills	Needed skill level (Min.): S	A	E	Training Outcome
	Read CS literature	A good start : https://www.cs-eu.net ; https://ecsa.citizen-science.net	CS literacy	√			Get acquainted with CS Philosophy & Principles To be able to take Go/no-go decisions
	Identify the type of CS project	One possible classification → Contributory / Collaboratory / Co-created					
Defining research questions	Develop a scientific literature review	Find relevant material, identify and analyse papers, synthesise the information etc.	Scientific literacy Writing skills		√		Be able to assess the state of the art and understand the needs for future research
	Write the rationale	Concise document including problem definition, the needs, the general objectives, the motivation, the expectations (the outputs), the benefits (including stakeholders benefits) and all relevant information	Scientific literacy			√	Be able to identify the motivations to launch the project (scientific, educational and society gaps to be filled by the project)
Gathering teams, partners & resources	Identify Stakeholder & identify methodologies to ensure commitment (stakeholder analysis)	Internal stakeholders: Persons involved in data and knowledge generation: Scientists / Teachers / trainers / participants	Management Networking Communication		√		Be able to build strategies to avoid conflicts during the project
		External stakeholders: Governmental agencies Industry					
	Identify funding opportunities	Funders can be the internal or external stakeholders mentioned in previous step: Crowd funding	Understanding of crowdfunding rules	√			Be able to estimate funding opportunities and resources
		Governmental funding (local, regional or national)	Understanding of the funding policies		√		
		EC funding (Horizon 2020, Horizon Europe, Erasmus+ etc.)	acquainted with EC programmes Grant application writing skills			√	
		Other (e.g. sponsoring, donation etc.)		√			

Designing and collecting and managing data	Design/run the data collection protocols	*Specific for each project* What observation/measurement is needed Define how the observation/measurement is collected	Scientific and technical skills			√	Be able to design/collect data and make a record according to methodology
Analysing and interpreting data	Define/use analysis methods	(e.g. summarise, find relationships, trends etc.) Define validation mechanisms (e.g. comparison against reference data)	Scientific technical skills				Be able to makes sense to the large amount of data collected in the step above (find meanings)
Dissemination results	Write a dissemination plan/publish results	Identify the audience (e.g. scientific community, policy makers), the timeline The channels (journals, conference, newspapers etc..) Write scientific article, blogs, press release etc.	Scientific skills Writing skills				Be able to make the outcomes of the project available to the appropriate stakeholders Be able to describe protocols and outcomes and viewpoints
Evaluating program success and participant impacts	Reveal the value of research investments	mention citations, downloads, page views, impact in social networks etc.	Scientific skills Other?			√	Be able to track and measure the impact of the obtained results within the scientific community to highlight the benefits of the research work
	Write a detailed project plan and supervise the progress of its the phases	Gather information from previous steps to write a Report including a Breakdown structure, a project schedule, milestones and deliverables, risk management plan etc. Communicate, lead, motivate , find solutions etc	Writing skills Project management skills Leadership skills		√		Be able to write a project plan Be able to manage a project and lead a team