O2 FabCitizen Competency Framework

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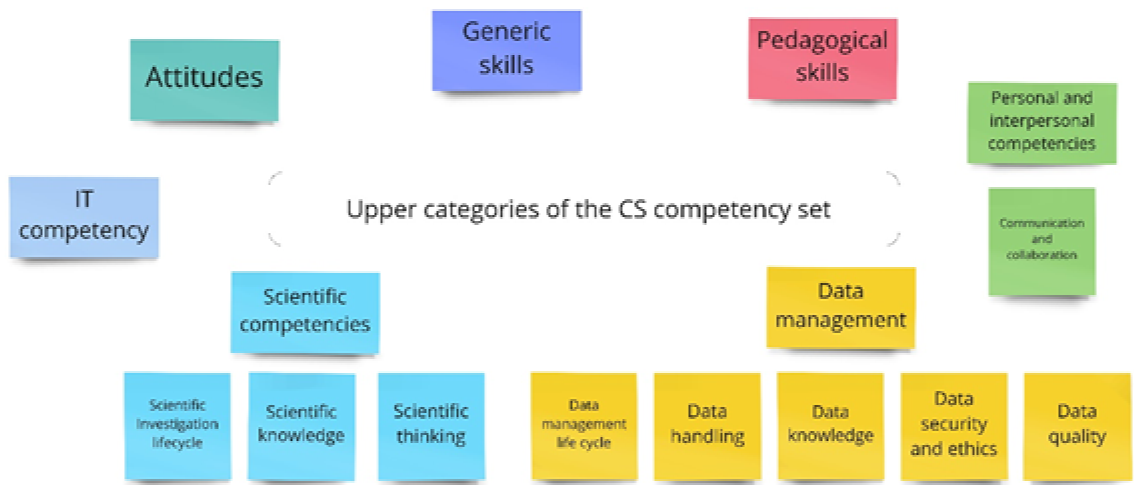


About this document

This document is the main outcome of IO2. It contains the second outcome as the conceptual framework for our project. Two parts are essential on the conceptual level: the curriculum for “Citizen Science" for grades 5-9 and the pedagogical framework. Furthermore, we intend to provide tools for transferring our approach, answering the questions: how can curriculum be changed to incorporate CS? How to transfer between the curriculum to different European countries. The outcome therefore consists of the following parts:

- Pedagogical framework (2.1) describing pedagogical and didactic assumptions and principles. This includes the outline of training needs for teachers to include service learning in their teacher education. It will specifically focus on the environment of FabLabs and similar environments as moderators and expertise providers.
- Competency Framework (2.2) outlining the curriculum for CS in schools (grade 5-9)
- Competency scheme (2.3) as a guideline to map curricula to the competence framework in other countries than the participating
- Competency mapping (2.4) to describe relations between the core competences of our curriculum to other possible subjects. All conceptual parts are based on previous, validated methods / concepts and will just be adapted for the European context. The base concepts are described below in the activity descriptions.

The outcomes are artifacts which are continuously validated throughout the project. This is reflected in the development.

- Initial version: After 9 months, an initial version of the outcome is published (V1). This reflects the initial working stage including pedagogical framework and curriculum / competence part.
- Second version: After the initial pilots (see O4), the results will be included to improve the competence framework and mapping.
- Final version: The large scale pilots will include further feedback and recommendations for improvement. Those will be finalized in Month 30 – the feedback will be included in the final version of the outcome.

About The Fab Citizen Project

The main goal is to enable schools, in particular teachers, parents and pupils, to participate in high quality citizen science projects in both curricular and extracurricular contexts.
Citizen Science (CS) has attracted a lot of attention in the last few years. Its main goal is to involve citizens in different types of science projects, in particular to 1) improve engagement and 2) to increase research capacities, e.g. by shared data collection. Many projects have incorporated citizen science approaches. Whereas citizen science works well for educational purposes (e.g. in inquiry-based science education), the acceptance of CS on a scientific level ranges from low to questionable. Even though the European Association for Citizen Science has clear guidelines and support mechanisms, many CS projects are not taken seriously. This is the main starting point for the FabCitizen project: We aim at providing tools to increase the quality of CS projects, in particular in schools. For this purpose, we will integrate FabLabs as the main educational environment as they can provide both technological as well as methodological expertise.
We base our project on clearly defined requirements, amongst them

- In schools, CS projects need to be embedded into the curriculum in various subjects
- To ease the implementation, teachers need high quality (open) scenarios and learning materials
- CS projects need support in terms of methodological and technological expertise.

In the project, we will achieve the following main results:

- A Citizen Science competency framework describing knowledge, skills and attitudes to successfully engage in high quality CS projects
- A pedagogical concept incorporating aspects of service learning to connect
- A guide for FabLabs as the key infrastructure to educate and train citizens.
- More than 100 Open learning scenarios to train teachers, pupils and parents in early secondary school
- A collection of Open Educational Resources supporting the approach
- A good practice guide for schools and FabLabs across Europe

The project will provide guidance and concrete support to universities, FabLabs, schools and the surrounding communities to participate in successful, high quality CS projects. As part of our trials, we will initiate around 100 CS projects. In the long run, we create new methods and materials for broader engagement and quality improvement in CS.

1 Background Competencies

1.1 Conceptual foundations: Competencies

We follow Pawlowski & Holtkamp (2012) defining “competency as a collection of skills, abilities, and attitudes to solve a problem in a given context”. Ferrari (2020) distinguishes the term “competency” in three areas: “knowledge, skills and attitudes”.In the following definitions are provided for “knowledge”, “skills” and “attitudes”.

Definition

> "*Knowledge refers to the result of assimilating information through learning. In addition knowledge is the collection of facts, principles, theories, and practices that can be related to a field of work or study can be associated with*." (Ala-Mutka, 2011, p. 19)

> "*Skills refer to the ability to apply knowledge and use know-how to complete tasks and solve problems*." (Ala-Mutka, 2011, p. 19)

> "*Attitudes can be understood as the motivators of performance. Attitudes include aspects such as ethics, values, and priorities*." (Ala-Mutka, 2011, p. 20)

Becker and Spöttl (2015) advocate a classification of competencies on the following levels (M. Becker & Spöttl, 2015, p. 14):

1. routine tasks
2. skilled structured tasks
3. unstructured tasks

Spöttl and Becker (2015) base their competency level model on the competency level model of Dreyfus & Dreyfus (1980). Through knowledge and increasing experience employees can improve their competency level. Dreyfus & Dreyfus (1980) provide the following level gradations for this purpose (Dreyfus & Dreyfus, 1980, pp. 2-14):

1. novice (novices)
2. advanced beginner (leaner)
3. competent actor (competent)
4. skilled professional (proficient)
5. expert (expert)

1.2 Competency Models for Citizen Science (responsibility: Annika)

First, for citizen science there exist less competency models (Jenett et al. (2016), Philipps et al. (2018), Aivelo & Huovelin (2020)) than for scientific literacy.

1.2.1 Scientific literacy

For scientific literacy exist more competency models than for citizen science (Kembara et al. 2020; Gormally et al. 2012, Queriga-Dios 2020, Holbrook & Rannikmae, 2009; Udompong, Traiwichitkhun, & Wongwanich, 2014; Norris & Philips, 2003).

Holbrook & Rannikmea (2009) provide an overview of scientific literacy with a focus on the "scientific" and "literacy" aspects (Holbrook & Rannikmae, 2009). They consider the teaching of scientific literacy by comparing "education through science" and "science through education". As research method was used a broad literature analysis. As foundational competencies, they define the following competencies (Holbrook & Rannikmae, 2009):

1. Knowledge of the substantive content of science and the ability to distinguish from non-science.
2. Understanding science and its applications
3. Knowledge of what counts as science.
4. Independence in learning science
5. Ability to think scientifically.
6. Ability to use scientific knowledge in problem solving.
7. Knowledge needed for intelligent participation in science-based issues.
8. Understanding the nature of science, including its relationship with culture.
9. Appreciation of and comfort with science, including its wonder and curiosity.
10. Knowledge of the risks and benefits of science; and
11. Ability to think critically about science and to deal with scientific expertise.

The purpose of **Udompong et al. (2014)** is to investigate the latent model of research literacy about teachers' and students' scientific literacy (Udompong et al., 2014). A qualitative method was used to validate the theoretical model and expert interviews were conducted. The researchers summarized the results of the survey in a model (see Figure 1).

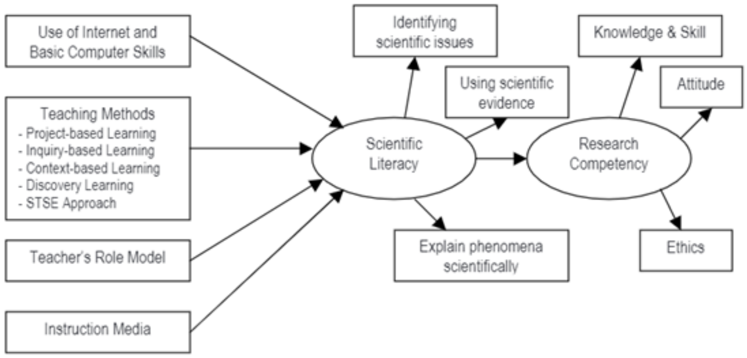


Figure 1: Causal model of research competency via scientific literacy (Udompong et al., 2014)

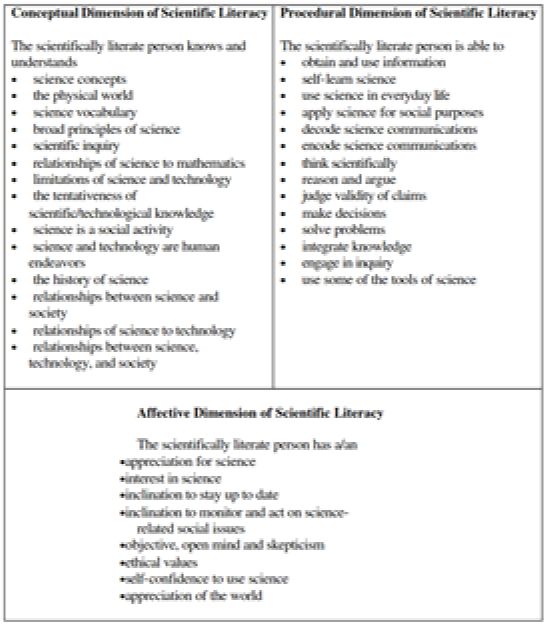
Kembara et al. (2020) did a study about the scientific literacy profile of student teachers. The research method they used was a mixed method with sequential explanatory design. Data were collected by 1) test of scientific literacy, 2) attitude scale and by 3) interviews.

Furthermore, they identified three main indicators of scientific competence (Kembara et al., 2020):

- Identifying scientific issues
- Explain phenomena scientifically.
- Using scientific evidence.

An important outcome of their study is that the ability of non-natural teacher candidates is very low in scientific literacy.

In the paper "Citizen Science for Scientific Literacy and the Attainment of Sustainable Development Goals in Formal Education" **Queruga-Dios et al. (2020)** deal with the promotion of Citizen Science in school education. As a model they use the 3 Dimensions - A Composite Outline View of Elements of Scientific Literacy Grouped by Dimension (see Figure 2).



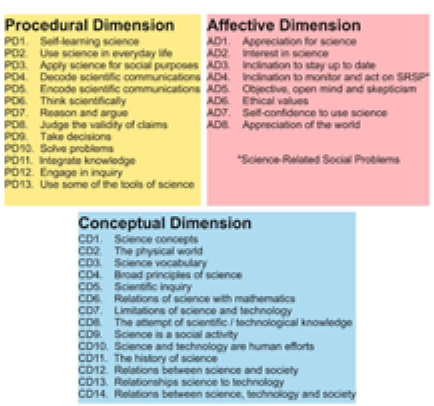
Conceptual Dimension of Scientific Literacy	Procedural Dimension of Scientific Literacy
The scientifically literate person knows and understands • science concepts • the physical world • science vocabulary • broad principles of science • scientific inquiry • relationships of science to mathematics • limitations of science and technology • the tentativeness of scientific/technological knowledge • science is a social activity • science and technology are human endeavors • the history of science • relationships between science and society • relationships of science to technology • relationships between science, technology, and society	The scientifically literate person is able to • obtain and use information • self-learn science • use science in everyday life • apply science for social purposes • decode science communications • encode science communications • think scientifically • reason and argue • judge validity of claims • make decisions • solve problems • integrate knowledge • engage in inquiry • use some of the tools of science
Affective Dimension of Scientific Literacy The scientifically literate person has a/an •appreciation for science •interest in science •inclination to stay up to date •inclination to monitor and act on science-related social issues •objective, open mind and skepticism •ethical values •self-confidence to use science •appreciation of the world	

Figure 2: A composite outline view of elements of scientific literacy groups by dimensions (Kemp, 2002 cited from Queiruga-Dios et al., 2020)

The following changes were observed among the students:

- increase in scientific literacy.
- increasing interest
- curiosity and appreciation of Citizen Science in everyday life
- discussions and advocacy as well as presentation of the information
- critical reflection

Furthermore, Queiruga-Dios et al. (2020) formulated the following overview of citizen science / scientific literacy competencies (Figure 3).



Procedural Dimension
PD1. Self-learning science
PD2. Use science in everyday life
PD3. Apply science for social purposes
PD4. Decode scientific communications
PD5. Encode scientific communications
PD6. Think scientifically
PD7. Reason and argue
PD8. Judge the validity of claims
PD9. Take decisions
PD10. Solve problems
PD11. Integrate knowledge
PD12. Engage in inquiry
PD13. Use some of the tools of science

Affective Dimension
AD1. Appreciation for science
AD2. Interest in science
AD3. Inclination to stay up to date
AD4. Inclination to monitor and act on SRSP*
AD5. Objective, open mind and skepticism
AD6. Ethical values
AD7. Self-confidence to use science
AD8. Appreciation of the world

*Science-Related Social Problems

Conceptual Dimension
CD1. Science concepts
CD2. The physical world
CD3. Science vocabulary
CD4. Broad principles of science
CD5. Scientific inquiry
CD6. Relations of science with mathematics
CD7. Limitations of science and technology
CD8. The attempt of scientific / technological knowledge
CD9. Science is a social activity
CD10. Science and technology are human efforts
CD11. The history of science
CD12. Relations between science and society
CD13. Relationships science to technology
CD14. Relations between science, technology and society

Figure 3: Overview of citizen science / scientific literacy competencies (Queiruga-Dios et al., 2020) adapted from (Kemp, 2002)

1.3 Competency Models for related topics

1.3.1 Data literacy

For data literacy there exist various competency models (Grillenberger & Romeike (2018), Ridsdale et al. (2015), Wolff et al. (2016), Bolhuis (2017), Pothier & Condon (2017), Prado & Marzal (2013), Sternkopf & Müller (2018), Mandinanch & Gummer (2016), Kippers et al. (2018)).

Grillenberger & Romeike (2018) develop a theoretically founded competency model for data literacy. The model is divided into two parts : content areas & process areas.
“Content areas reflect the CS content addressed by the competencies” (Grillenberger & Romeike, 2018, p. 3) and “Process areas emphasize the practical activities.” (Grillenberger & Romeike, 2018, p. 3). The process area displays how humans can get into touch with data whereas the content area considers the theoretical background and the underlying concepts. Due to this fact, both areas are hard intertwined with each other.

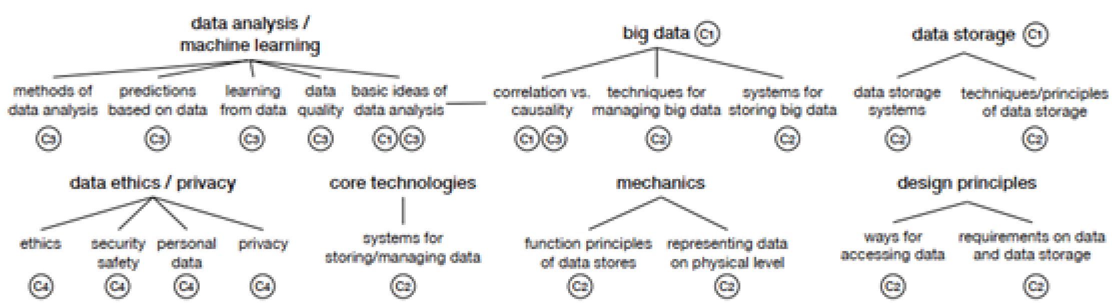


Figure 4: Division of the candidates for the content areas (Grillenberger & Romeike, 2018)

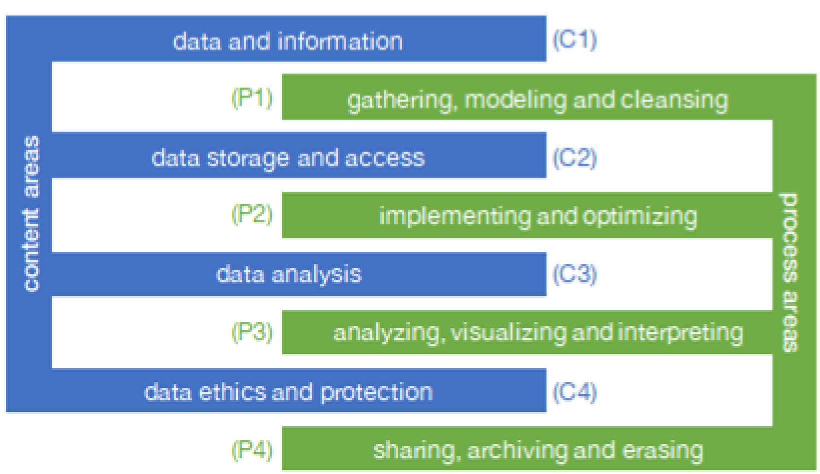


Figure 5: The developed data literacy competency model (Grillenberger & Romeike, 2018)

In addition, **Ridsdale et al. (2015)** define a competence matrix with the following five competence areas for the field "Data Literacy"

- Conceptual framework
- Data collection
- Data management
- Data evaluation
- Data application

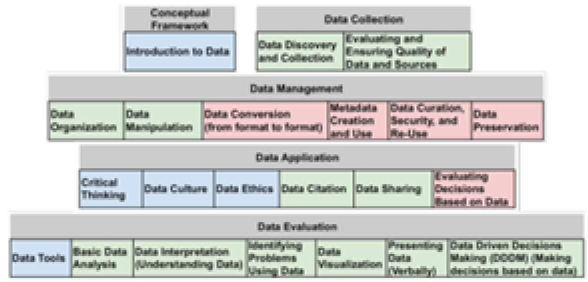
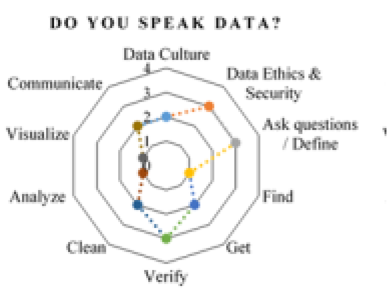


Figure 6: Data Literacy Competencies (Ridsdale et al. 2015)

Sternkopf & Mueller (2018) develop a **data literacy maturity model** (DLMM). The DLMM describes eleven data literacy competencies. The model should help to improve the understanding which skills are needed in the context of data projects (Sternkopf & Mueller, 2018, p. 5045). The application context of the maturity model is non-governmental organizations.

Figure 7: Example Output from the DLMM self evaluation tool (Sternkopf & Mueller, 2018)



Sternkopf & Mueller (2018) define the following **competency levels** for data literacy (Sternkopf & Mueller, 2018, p. 5051):

- uncertainty
- enlightenment
- certainty
- data fluency

Furthermore, they define **eleven competency areas** for data literacy:

	Competence	Description
Organizational	Data Culture	Promoting comfort around data (and bringing down the psychological barriers that exist between people and data).
	Data Ethics & Security	Processes that are in place to ensure confidentiality, integrity, and availability of data is adequately protected.
Individual	Ask question / Define	Ability to ask adequate questions to data and ultimately find answers
	Find	Track down sources of existing data, know how to collect data if it does not exist yet
	Get	Describes gaining access to data or generating fresh data as well as conversion of different input formats
	Verify	Apply critical thinking skills to data. Ability to do data quality assessment, contextualizing specific information to other aspects
	Clean	Removing invalid records and translating columns to use a sane set of values
	Analyze	Ability to work with statistics and other analytical methods
	Visualize	Ability to represent findings in appropriate visual outputs
	Communicate	Importance of finding stories and communicating them to the targeted audience

Figure 8: Definition and Description of mentioned competencies (Sternkopf & Mueller, 2018)

1.4 Competency Descriptions

There are a variety of competency description schemes in order to ensure a common vocabulary and structure of competencies.

As a first approach, common vocabularies have been developed, often on the basis of the learning outcome taxonomies of the cognitive domain (Bloom et al, 1956) and affective domain (Krathwohl et al, 1964). An example for such a taxonomy are the levels and corresponding verbs by Paquette (2014)-

Generic Skills Taxonomy Layers		
1	2	3
Receive	1. Pay Attention	
	2. Integrate	2.1 Identify 2.2 Memorize
Reproduce	3. Instantiate / Specify	3.1 Illustrate 3.2 Discriminate 3.3 Explicitate
	4. Transpose/ Translate	
	5. Apply	5.1 Use 5.2 Simulate
Create	6. Analyze	6.1 Deduce 6.2 Classify 6.3 Predict 6.4 Diagnose
	7. Repair	
	8. Synthesize	8.1 Induce 8.2 Plan 8.3 Model/ Construct
Re-invest	9. Evaluate	
	10. Self-manage	10.1 Influence 10.2 Self-control

Figure 9: Skill Taxonomy (Paquette, 2014)

Other approaches focus use ontologies such as the SARO ontology for relating job postings and structured skills (cf. Sibarani et al, 2017).

For our project, the main purpose is to describe competencies in an interoperable way and to link competencies to different curricula.
Our competency description aims at describing in depth competencies and their links to school curricula.

- **Competency description** describes the competency. A competency can consist of multiple skills, abilities and attitudes.
- **Competency statement** provides an operational statement which can be assessed.
- **Competency classification** describes the main subject of a competency (e.g. Scientific literacy, data literacy, …)
- **Proficiency level** describes levels of mastering competencies. In our context the levels are differentiated by roles
- **Role / level** describes either a role or a level / grade in school
- **Curriculum mapping** links a competency to one or multiple curricula.

This simple scheme fulfills the main purpose of our project - specifying a competency framework including links to national / state / school curricula.

1.5 Intermediate Summary

As a first step, the CS concept has been identified as important. In addition, scientific literacy (SL) has been identified as a related concept and is therefore integrated in the literature analysis. Moreover, one important goal of CS projects is to enhance the citizens' SL levels (Levy & Germonprez, 2017). Therefore, one focus is also put on data-related competencies, because data quality is considered a significant problem in CS projects (Balázs et al., 2021; Lukyanenko et al., 2016), which should be improved using a fitting competency framework that includes data-related competencies for CS. The competency framework for educational CS should fit to competencies for undertaking CS projects in secondary school I, where data literacy is considered since it is perceived as "an important forerunner to data science and incorporates key skills in identifying, collecting, and analyzing data" (Sentance, 2017, p. 81). Because data science competencies are too complicated for secondary school I, this concept is not considered, and instead data literacy (DL) is integrated into the competency framework.

The following competency areas were identified in the first analysis:

- **Scientific literacy** (Gormally, Brickman, & Lutz, 2012; Holbrook & Rannikmae, 2009; Kembara et al., 2020; Norris & Phillips, 2003; Udompong, Traiwichitkhun, & Wongwanich, 2014);
- **Citizen science** (Aivelo & Huovelin, 2020; Bonney, Ballard et al., 2009; Jennett et al., 2016; Phillips, Porticella, Constas, & Bonney, 2018; Queiruga-Dios, López-Iñesta, & Diez-Ojeda, Marío, José Benito, 2020);
- **Data literacy** (Bolhuis, Voogt, & Schildkamp, 2019; Grillenberger & Romeike, 2018; Prado & Marzal, 2013; Ridsdale et al., 2015; Sternkopf & Mueller, 2018; Wolff, Gooch, Montaner, Rashid, & Kortuem, 2016);
- **Data science** (Donoho, 2017; Murawski & Bick, 2017; Sentance, 2017; Shirani, 2016)

2 Background: Pedagogical Approach

2.1 Inquiry Based Learning

Jenkins (2011) pointed out some positive effects of inquiry-based learning within CS projects. In the following, a definition is provided for inquiry-based learning.

Definition: **Inquiry-based learning**

> *"Inquiry-based learning is an educational strategy in which students follow methods and practices similar to those of professional scientists in order to construct knowledge"* (Keselman, 2003, cited by Pedaste et al., 2015, p. 48).

The aim of inquiry-based learning is to involve students in the scientific discovery process. Therefore, smaller units called 'inquiry phases' are created on the basis of the scientific process (Pedaste et al., 2015), and several 'inquiry phases' are used to form a scientific process. According to Bybee et al., 2006, cited by Pedaste et al., 2015, there are five inquiry phases: engagement, exploration, explanation, elaboration and evaluation.

Based on the findings of the conducted literature review, Pedaste et al. (2015) created an inquiry-based learning framework including five inquiry phases (see Table 5).

Table 2: Phases and sub-phases of the inquiry-based learning framework of Pedaste et al. (2015, p. 54)

General phases	**Definition**	**Sub-phases**	**Definition**
Orientation	The process of stimulating curiosity about a topic and addressing a learning challenge through a problem statement.		
Conceptualization	The process of stating theory-based questions and/or hypotheses.	Questioning	The process of generating research questions based on the stated problem.
		Hypothesis Generation	The process of generating hypotheses regarding the stated problem.

Investigation	The process of planning exploration or experimentation, collecting and analyzing data based on the experimental design or exploration.	Exploration	The process of systematic and planned data generation based on a research question
		Experimentation	The process of designing and conducting an experiment to test a hypothesis.
		Data Interpretation	The process of making meaning out of collected data and synthesizing new knowledge.
Conclusion	The process of drawing conclusions from the data. Comparing inferences made based on data with hypotheses or research questions.		
Discussion	The process of presenting findings of phases or the whole inquiry cycle by communicating with others and/or controlling the whole learning process or its phases by engaging in reflective activities.	Communication	The process of presenting outcomes of an inquiry phase or of the whole inquiry cycle to others (peers, teachers) and collecting feedback from them. Discussion with others.
		Reflection	The process of describing, critiquing, evaluating, and discussing the whole inquiry cycle or a specific phase. Inner discussion

Notably, CS and inquiry-based learning are closely linked, as inquiry-based learning is used as a didactic teaching method in many CS projects (Raddick et al., 2009; Sharples et al., 2017). In addition, both concepts are summarized under the term ‘citizen inquiry’. There are also some platforms and webtools (e.g. nQuire) (Herodotou et al., 2018) that are used to support citizen inquiry (i.e. both online CS projects and inquiry-based learning approaches).

2.2 Service Learning

Service Learning (SL) is a form of experiential education which integrates meaningful community service into a learning environment. According to Preradovic (2015)[1], service science understanding can be divided into two groups: (1) SL as a form of education; and (2) SL as an educational philosophy. In this review, we will focus on the first one. Service Learning in this frame of understanding, is closely related to student volunteerism. However, some

[1] Preradovic, M. (2015). Service-Learning. *Encyclopedia of Educational Philosophy and Theory. Singapore: Springer*, 1-6.

noticeable differences exist. According to Eyler & Giles (1999)[2], in SL both the student and the community are equal and direct beneficiaries. There is a growing body of research into SL as a transformative pedagogy approach for the students (Mergler et al. 2017)[3].

Service-Learning stands out as a form of teaching which connects theory and practice by giving students the opportunity both to participate in an organized service activity that meets community needs and to reflect on the experience in class in order to gain a deeper understanding of the course content and an enhanced sense of civic engagement (Bringle, Hatcher & McIntosh, 2006)[4]. From this definition, SL can be interpreted based on three essential elements: service, learning and reflection. This means that learning does not necessarily occur as a result of learning experience but as a result of reflective components explicitly designed to foster learning (Jacoby, 2014)[5].

Chamber & Lavery (2017)[6] four type activities attributed to SL: a direct service for people in need, an indirect service for broader issues in the community without personal contact to people in need, advocacy for people in need or community-based research. Here, it's where the connection between Citizen Science and Service Science can be seen most clearly. Some CS communities already offer student possibilities to fulfill their service hour requirement through their platforms. One notable example is Zooniverse (Zooniverse, 2021). Some other research-based examples of service learning include: (1) Writing a guide on available community services and translating it into Spanish and other language; (2) Conducting longitudinal studies of local bodies of water; water testing for local residents; (3) Gathering information and creating brochures or videos for non-profit agencies; and (4) Mapping state lands and monitoring flora and fauna (FSCJ Center for Civic Engagement, 2021). Up until recently, SL was mostly related to offline activities of students in their immediate communities. However, technological development has brought SL closer to digital technologies and most importantly digital communities.

According to the US-based National Youth Leadership Council[7] (2008), all forms of Service-Learning should meet certain quality criteria, in particular with regard to the meaningfulness of the service, link to the curriculum, reflection, partnerships and diversity. This means if we incorporate Service Learning in developing learning scenarios during project duration - partnerships with research-based institutions or local communities have to be established. Another element that needs in-depth considerations is the reflection part of the

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[2] Eyler, J., & Giles Jr, D. E. (1999). *Where's the Learning in Service-Learning? Jossey-Bass Higher and Adult Education Series*. Jossey-Bass, Inc., 350 Sansome St., San Francisco, CA 94104.
[3] Mergler, A., S. B. Carrington, P. Boman, M. P. Kimber, and D. Bland. 2017. “Exploring the Value of Service-Learning on Pre-service Teachers.” *Australian Journal of Teacher Education* 42 (6): 69–80. doi:10.14221/ajte.2017v42n6.5.
[4] Bringle, R. G., J. A. Hatcher, and R. E. McIntosh. 2006. “Analyzing Morton’s Typology of Service Paradigms and Integrity.” *Michigan Journal of Community Service Learning* 13: 5–15.
[5] Jacoby, B. (2014). *Service-learning essentials: Questions, answers, and lessons learned*. John Wiley & Sons.
[6] Chambers, D., and S. Lavery. 2017. “Introduction to Service-Learning and Inclusive Education.” *Service-Learning*, November 22. doi:10.1108/S1479-363620170000012001
[7] National Youth Leadership Council. 2008. “K-12 Service-Learning Standards for Quality Practice.” Accessed 18 November 2020. https://www.nylc.org/page/standards.

projects. SL is often critiqued because of its strong emphasis on reflection in evaluation of students. Clayton et al. (2013)[8] state that reflection is hard to assess and complicates evaluation process.

2.3 FabLabs as the Learning Environment (in progress)

- Describe FabLabs in general
- Describe what is the relation to CS & to our project
- Apprenticeship

2.4 The FabCitizen Pedagogical Model

2.4.1 Artifact creation

We base our artifact creation on the following findings from the literature:

- Citizen Science is no research about citizen scientists (European Citizen Science Association & others, 2015)
- Conduction of 'participatory science' and 'extreme science' projects (Haklay, 2013) to allow citizen science students to participate more deeply in the scientific process
- Computer science related citizen science topics which fit to competencies of the curricula (Schulministerium NRW, 2021)
- Focus on data-related competencies as many CS-projects lack of data-quality (Lukyanenko et al., 2016)

But these findings from the literature are not the only basis for constructing the methodology, but also further guidelines, frameworks, and steps. The creation of the artifact will be described in the following.

[8] Bringle, R. G., Hatcher, J. A., & Clayton, P. H. (Eds.). (2013). *Research on Service Learning: Conceptual Frameworks and Assessments: Students and Faculty* (Vol. 3). Stylus Publishing, LLC.

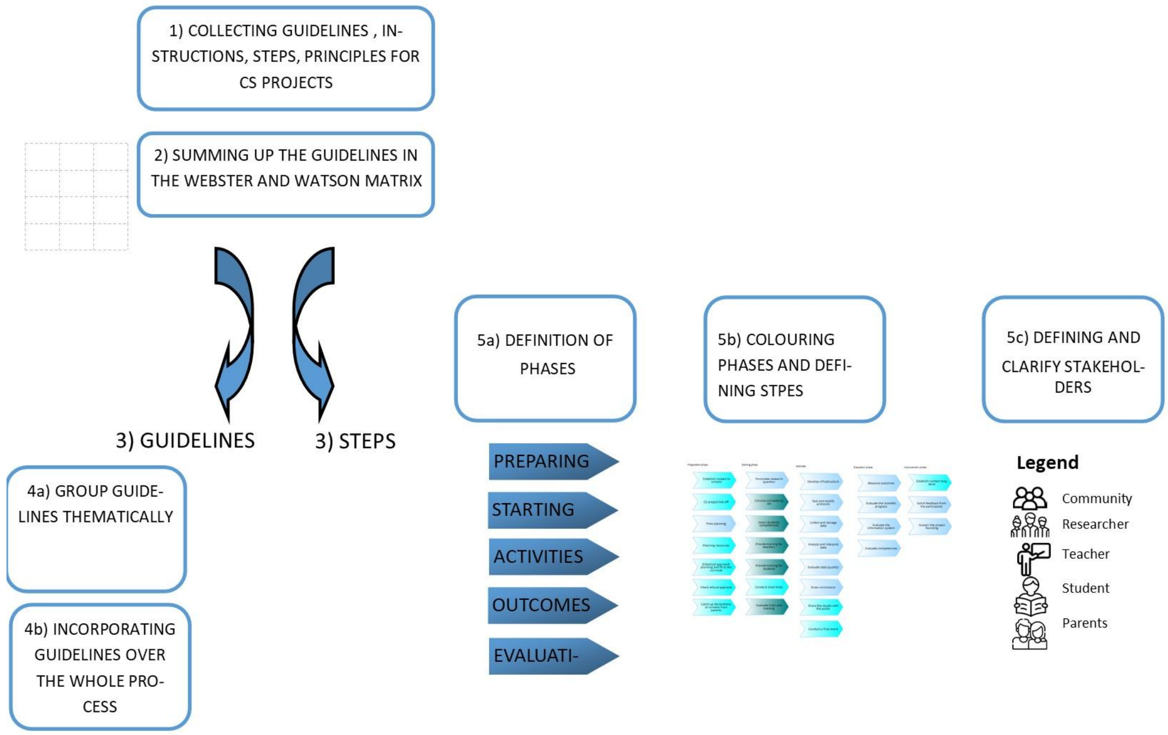


Figure 10: Derivation of the competency-based methodology for educational CS in IS (own illustration)

First, the decision was not to model a detailed process, but to **model a process map**. This decision is because some process phases are flexible and can run in parallel. Furthermore, it is a **generic method** that should be adapted to the respective school context. The starting point (see point 1 in Figure 10) is the literature review and the creation of the concept matrix of Webster and Watson (2002) (see point 2 in Figure 10), which contains guidelines, instructions, (process) steps and principles for the implementation of CS projects in schools.

Another decision is to have a **subdivision into steps and guidelines** (see point 3 in Figure 10). A step is understood in this paper as a “process that has to be executed concretely and has a defined beginning and end” (own definition), while the understanding of a guideline in this paper is that a “guideline an instruction or guideline that applies and has to be followed over the entire project period or part of the project period” (own definition). An example of a guideline is 'communicate effectively' and an example of a step is: 'conduct a project meeting'. Also, some aspects can be both a guideline and a step, depending on the perspective from which they are viewed. An example of this is: 'Pupils can do different tasks in projects and choose them according to their interests’. For pupils it is a step since it is an executable action whereas it is a guideline for researchers. Furthermore, in step 4a) in Figure 10, the guidelines are thematically grouped into head categories, so that later design principles can be formed from them.

The initially thematic order of the (process) steps is changed into a temporal order. For this purpose, the project phases of Shirk et al. (2012) and Bonney, Cooper et al. (2009) are used.

This results in five main project phases: preparing, starting phase, activities, evaluation, and future planning (see Figure 10). In the next step, the necessary processes are collected and summarized on the process map (see 5b) in Figure 10). In addition, coloring is done to indicate school-specific, competency-based, and standard processes.

To also represent the temporal component to some extent, it applies first that the process from right to left (oriented at the project phases) and within the project phases from above down runs off. Since some processes can also run in parallel, this is marked by dashed lines. The dashed lines make it clear that the order of the processes within them can be interchanged. This makes it easier for the viewer or reader to understand the underlying processes. Since in a process always also actors are involved and straight the participation in the CS context is away, the actors at the processes are also marked (see 5c) in Figure 10). The focus is more on the involvement of the school than on the community, as the methodology is developed for the educational sector. However, this is freely adaptable, as the methodology is generic. The result is a process map with color-coded processes (school-oriented, competency-based, standard process) and CS actors.

Moreover, we define our own **principles for design** which will be incorporated into the method design.

2.4.2 Principles for Design

- **Design principle 1: Competency-based approach for conducting CS projects**

The competency-oriented CS approach means that the participants, in the educational context of pupils, are equipped with appropriate competencies which can be easily and appropriately integrated into the lessons. As a basis for the needed competencies in CS, the revised CS-DL-SL competency set of Nowak et al. (2021) can be used. Additionally, the design principle answers the sub research question mentioned in the beginning of this work which competencies are required for students and teachers to conduct CS projects. In addition, the competency-based approach includes the above-mentioned training, which equips students and teachers with appropriate skills to successfully implement CS projects. Consequently, the lack of data quality in CS projects (Lukyanenko et al., 2016) can be reduced by the application of comeduCIS.

- **Design principle 2: Focussing on the curricula fit**

Linking competencies to the curricula and specifying the appropriate subjects in the learning scenarios, enable teachers to integrate CS more easily into the classroom (Kloetzer et al., 2021; OEAD, 2021). For this purpose, the (revised) CS-DL-SL competency set of Nowak et al. (2021) can be used that includes competencies for CS projects and identifies which CS competencies overlap with STEM curricula topics and competencies.

- **Design principle 3: Using OER materials to create learning scenarios**

For the development of learning scenarios which can be used in trials for training purposes, it is helpful to draw on existing learning materials, such as OER materials. If the OER materials are distributed under a CC BY SA, CC BY or Public Domain license (creative commons, 2021), materials can be edited, shared and made publicly available. In addition, existing OER materials can be tailored to the needs of educational CS trials or projects. The advantage of this is that they are accessible free of charge.

- **Design principle 4: Conduct trials and use the learning scenario template**

The fourth design principle is closely linked to the first design principle as the 'competency-based approach for undertaking CS projects' forms the basis for the fourth design principle. Furthermore, the development of the learning scenarios used in trials builds on the competency set of Nowak et al. (2021). By conducting the trials, it can be ensured that the participants are equipped with the necessary competencies for educational CS (Tweddle et al., 2012). By equipping the students with the appropriate (data) competencies, problems with data quality in CS projects (Lukyanenko et al., 2016) should be prevented. In addition, the use of the adapted learning scenario template (based on Nikolov et al., 2014) facilitates the integration into school lessons, as the topic, the learning activities, the educational approach and also the acquired competencies (based on the STEM curricula) and further competencies of the learning scenario are recognisable at a glance. In addition, the linked worksheets in the learning scenarios offer a reduction of the workload for teachers, as the worksheets are ready to be handed out to the students and no further work is needed.

These **four design principles** are a crucial contribution regarding design principles for educational CS in IS since they facilitate undertaking CS projects with schools, minimize costs, improve student's competencies, prevent problems of data quality, and provide guidance for developing a methodology for educational CS.

Further design principles described in based on existing literature are:

- Collaboration with schools' principles
- Project setup principles
- Ethical and legal principles
- Communication principles
- Evaluating outcomes principles
- Data principles
- Project improvement principles
- Participant's principles
- Scientific principles

An overview of the content of the principles is displayed in Figure 10.

Figure 11: Overview of the found guidelines for undertaking CS projects resulting from the Webster and Watson (2002) matrix in Appendix 2

One example of a design principle for participants is that students should not only collect data, but **students should actively participate deeply** in the project. This includes the whole scientific inquiry cycle which was formulated by Shirk et al. (2012) reaching from choosing a question for study until discussing results and ask new questions

In addition, regarding ethical and legal principles, one important criterion is the **compliance with the German Data Protection Regulation** (DSGVO). The basis of data protection for children is in particular Art. 8 of the DSGVO (GDPR) "Conditions for the consent of a child in relation to information society services". In particular, if the children are under 16, consent of the parents is needed for the personal processing of data. This can also be the keeping of subscriber lists. Furthermore, the DSGVO regulations are to be complied with in all cases. In addition, there are also possibilities to avoid the personal processing of children's data. These can be, for example, accounts that have already been set up by an institution. In the summer course, for example, tablets were used to programme apps with the AppInventor programme. Accounts are needed to use AppInventor. For this purpose, accounts were created in advance by the university so that the children do not need to create accounts.

An **interdisciplinary design of learning scenarios** means combining different subjects, such as physics, technology, sports, biology or other subjects with computer science, so that learning scenarios are created that promote competences from different subjects. This can be applied in practice, especially in the areas of physics, technology or biology.

2.4 Methodology visualization

All these guiding principles lead to the construction of the following methodology which is based on the structure of (Bonney, Cooper, et al., 2009) and (Shirk et al., 2012).

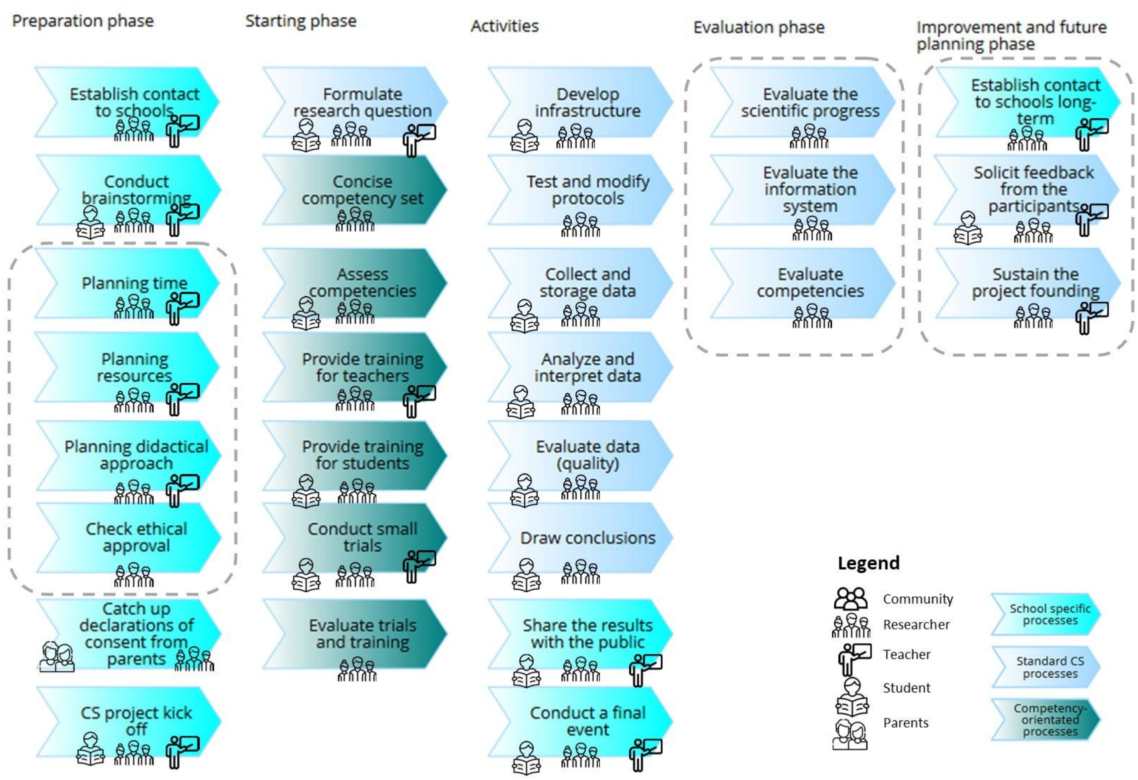


Figure 12: Generic competency-based methodology for educational citizen science projects in Information Systems (comeduCIS)

2.5 Methodology description

The **comeduCIS** displayed in Figure 12 consists of five upper phases: the preparation phase, the starting phase, activities, the evaluation phase and the improvement and future planning phase. In addition, the **stakeholders** involved in each phase or process are marked. In addition, a **temporal visualization** was undertaken. The processes that can run in parallel or can also be interchanged by the sequence are marked in a dashed area. All other processes run from left to right starting from the upper phases and from top to bottom within the phases. In addition, a **color coding of the processes** was carried out. The turquoise processes are school-specific processes that have been adapted to the context of the school. The standard processes were marked in light blue and the competency-oriented processes in turquoise.

2.5.1 Phase 1: Preparation phase

The preparation phase encompasses the establishment of contact with schools, to conduct a brainstorming with teachers, researcher's and pupils, the time and resources planning as well as the planning of the didactical approach, the ethical approval, the catch of the declarations of consent from parents and finally the project kick-off.

2.5.1.1 Establish contact with schools

To establish the connection to schools, it is useful to come to the schools before the project planning is started (OEAD, 2021). This enables getting to know each other and gives teachers the opportunity to gain an initial understanding of CS projects.

2.5.1.2 Conduct brainstorming

In the brainstorming phase, topics for CS projects can be discussed. Since participatory CS projects should consider scientific and student interests (Senabre Hidalgo et al., 2021), it is important to undertake steps to integrate both interests into the model; however balancing the interests of students and researchers is a challenge (Kloetzer et al., 2021). To find new topics for CS in IS or to identify topics of interest, it is valuable to ask teachers and students about their interests. Brainstorming sessions are recommended for this purpose, which reflect the perspective of the researchers and can incorporate the experience from research.

2.5.1.3 Planning time

Time planning should be considered in CS projects because schools and universities have different timetables, one must be aware of both timetables, including overlaps and specific aspects. University includes lecture-free and exam-intensive periods, whereas schools have autonomous days and exam-intensive periods at different times. Moreover, one recommendation is to conduct project planning meetings with schools in May and June because this is when the planning occurs for the next school year. In addition, time planning includes finding free space in lesson series or considers the implementation of project days. Concerning the integration of CS projects into the curricula, elective subjects or free hours for project work in the curricula plan can be used. (OEAD, 2021)

2.5.1.4 Planning resources

Resource planning includes financial, personnel and spatial aspects. A first step is to conduct a cost analysis and funding and to plan material, spatial and personnel resources (OEAD, 2021; Tweddle et al., 2012; U.S. GSA, 2021; Yadav & Darlington, 2017).

2.5.1.5 Planning didactical and fit to the curricula

Since the connection to the curricula is a challenge of CS in formal education (Kloetzer et al., 2021), it is useful to provide a fit between the curricula and the trained and learned competencies in the CS project. The competency set based on Nowak et al. (2021) was used as input for the methodology. As described later in *Chapter 5.2*, the competency upper categories were reduced from 83 of Nowak et al. (2021) to seven containing nine sub-upper categories. This step facilitated mapping the school curricula and overcoming the barrier 'connection to the curricula'.

2.5.1.6 Check ethical approval

Before starting the project, it needs to be checked whether an ethical approval from the directorate of education is needed. Furthermore, questions about the assurance of the guiding project staff and the participants should be answered. (OEAD, 2021)

2.5.1.7 Catch up declarations of consent from parents

For undertaking CS projects at schools, declarations of consent for participation are needed from the parents (OEAD, 2021) as well as photo consent forms.

2.5.1.8 CS project kick-off

The kick-off and initial narrowing down of the topics are followed by further planning for integration into the lessons and for the didactic concept and process. Furthermore, the kick-off also forms a team consisting of scientists, educators, evaluators and leaders (Bonney, Cooper et al., 2009; Harris & Ballard, 2018; Tweddle et al., 2012).

2.5.2 Phase 2: Starting phase

The starting phase encompasses the formulation of a research question, specification of the competency set, the assessment of student and teacher competencies, providing training for students, conduction of trials and the evaluation of the trials and the training.

2.5.2.1 Formulate research question

To follow the steps of the scientific inquiry circle, one first defines a question or issue that is of interest to students and researchers (Bonney, Cooper et al., 2009; Harris & Ballard, 2018; Heigl et al., 2020; Shirk et al., 2012). It is important that the research question fits the planned CS design and is suitable for a CS approach (Pocock et al., 2013).

2.5.2.2 Concise competency set

One step is to revise the set of competencies to train appropriate competencies for the CS projects. The set is adapted to which competencies are necessary to execute the CS project for pupils and teachers. The extent to which pupils are involved in the phases of the scientific inquiry circle was determined during the didactic planning beforehand.

2.5.2.3 Assess competencies

To assess competencies and initially determine the competencies of students and teachers, they both conduct self-assessments of competencies of the above-mentioned set to get to know the skill level of participants (U.S. GSA, 2021). In the case of strong competency gaps, special focus is placed on this step in the training (Pocock et al., 2013; Tweddle et al., 2012).

2.5.2.4 Provide training for teachers and students

Sample learning scenarios examples are provided to undertake CS training. Furthermore, the structure of the learning scenarios serves as a template for developing new learning scenarios and is based on Nikolov, Shoikova, and Kovatcheva (2014) and can be found in *Appendix 3: Learning scenario template orientated on Nikolov et* al. (2014). The training can be developed based on these learning scenarios to teach competencies from the specified competency set. Teachers and students receive joint training from researchers.

2.5.2.5 Conduct small trials

To gain initial experience with school groups, it is helpful to first conduct small trials to gain more experience, which can be used to further develop the competency-based method for the school context (Tweddle et al., 2012).

2.5.2.6 Evaluate trials and training

One step is to revise the set of competencies to train appropriate competencies for the CS projects. Based on the revised competency set, the next steps, providing training for teachers and students, will be conducted (Tweddle et al., 2012). The training is tailored to the previously defined set of competencies so that both teachers and students will gain the necessary competencies to successfully implement the CS project. To review and monitor the success of the training and, the training will be evaluated (e.g., using a self-assessment form).

2.5.3 Phase 3: Activities

To give students the opportunity to improve, participants receive feedback during the whole phase of activities and researchers give support (European Citizen Science Association & others, 2015; Pocock et al., 2013; Tweddle et al., 2012; U.S. GSA, 2021).

2.5.3.1 Develop infrastructure

The first step is to develop and provide infrastructure, where IT support is important to implement the project since some schools lack Wi-Fi, tablets or other hardware (Nowak et al., 2021). As an orientation for the deployment of the CS application, the categorisation framework from Yadav and Darlington (2017) can be used, including the deployment process . The infrastructure must fit the data to be collected (Herodotou et al., 2018; U.S. GSA, 2021). Possibilities of infrastructure are, for example, a mobile application to scaffold data collection or the deployment of a thin or thick client or to perform sensor data processing (Yadav & Darlington, 2017).

2.5.3.2 Test and modify protocols

Protocols for collecting data should be tested and modified (Pocock et al., 2013; Tweddle et al., 2012).

2.5.3.3 Collect and store data

The data then need to be collected and accepted, edited and displayed in a further step (Bonney, Cooper et al., 2009; Tweddle et al., 2012). Furthermore, data is stored safely (U.S. GSA, 2021).

2.5.3.4 Analyze and interpret data

To gain further insights about the data, they are analyzed and interpreted (Bonney, Cooper et al., 2009; Harris & Ballard, 2018; U.S. GSA, 2021; Yadav & Darlington, 2017). Furthermore, the data is visualized (Tweddle et al., 2012).

2.5.3.5 Evaluate data quality

Because many CS projects lack data quality (Lukyanenko et al., 2016), evaluating data is an important step. Furthermore, data quality can be evaluated in relation to several dimensions (e.g., completeness, accuracy, consistency) (Mäkipää et al., 2020).

2.5.3.6 Draw conclusions

Findings are then drawn from the collected and analyzed data. For this purpose the data can be visualized (Tweddle et al., 2012). In addition, the research question posed at the beginning should be addressed and an answer provided (European Citizen Science Association & others, 2015).

2.5.3.7 Share the results with the public

Data can then be shared, uploaded and be made publicly available (European Citizen Science Association & others, 2015; Harris & Ballard, 2018; Heigl et al., 2020; U.S. GSA, 2021). The results should be disseminated and finally published with open access (Bonney, Cooper et al., 2009; Heigl et al., 2020; Tweddle et al., 2012; U.S. GSA, 2021).

2.5.3.8 Conduct a final event

Furthermore, the results of the CS project can be presented at a school in the context of a final event or presentation in class (Harris & Ballard, 2018). At this point, one could also examine the possibility of submitting the results in the context of competitions, such as ‘Youth research’s and thus an additional final and appreciative event can take place.

2.5.4 Phase 4: Outcomes

In the third step, the outcomes should be evaluated according to the evaluation framework of Kieslinger et al. (2018). The outcomes are threefold and orientated based on the model for public participation in research of Shirk et al. (2012):

- Advancement in scientific knowledge
- Social-ecological outcomes
- Skills

2.5.4.1 Evaluate the scientific progress

The outcomes for science could be achieved through the investigations of citizen scientists in a subject area. This encompasses improved scientific understanding, as well as scientific publications and large-scale projects. (Shirk et al., 2012)

2.5.4.2 Evaluate social-ecological outcomes

With regard to social-ecological systems, outcomes can be “improved relationships between communities and management agencies (Tudor and Dvornich 2001, Ballard et al. 2008), backyard enhancement of wildlife habitat (Evans et al. 2005), access to and use of data to address environmental degradation (Overdevest and Mayer 2008), and increased likelihood of participant engagement in policy processes to improve their surroundings (Overdevest et al. 2004, Wilderman et al. 2004a)" cited from Shirk et al., 2012, p. 9).

2.5.4.3 Evaluate competencies

To review and monitor the success of the CS project, the teachers and students perform a self-assessment of their competencies after the project. The competencies for evaluation can be taken from the adapted competency framework for CS from (Nowak et al., 2021).

2.5.5 Phase 5: Improvement and future planning phase

The improvement and future planning phase encompass the establishment of contact with schools long-term, soliciting feedback from the participants and sustaining the project funding.

2.5.5.1 Establish contact with schools long-term

To establish CS projects in the long term, it is recommended to define CS contact persons in universities and research institutions. Furthermore, network meetings and other meetings are a useful method to stay in touch, such as the OeAD Center, which organizes such network meetings for the contact persons in Austria. Furthermore, it is recommended to establish a contact point for CS in schools. (OEAD, 2021)

2.5.5.2 Solicit feedback from the participants

To evaluate the experience and cooperation with researchers, students and scientists, it is recommended to conduct an open feedback session at the end of the project to improve future projects and cooperation (OEAD, 2021).

2.5.5.3 Sustain the project founding

Funding opportunities should also be sought for the future to be able to finance further CS projects (OEAD, 2021).

3 Competency Framework Construction

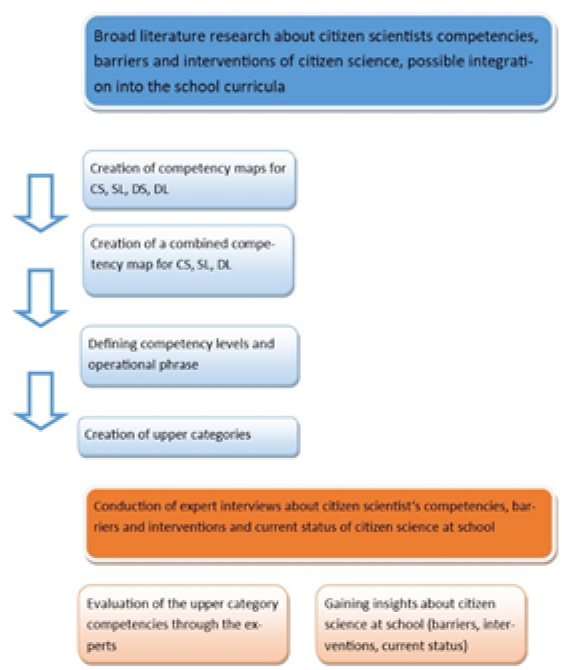
Based on the initial analysis, we aimed at thoroughly understanding requirements and barriers in schools. In the following, we show our study design and results.

3.1 Methodology

For our analysis, we have chosen a qualitative approach. As shown in the background section, there are no extensive analyses of how Citizen Science can be brought into schools. Furthermore, there are many differences (curricula, technical equipment, competencies, …) in the participating countries. For this explorative research task, we decided to do semi-structured interviews as well as focus groups. The interviews were - when authorized - recorded and transcribed. The full interview guideline is shown in Annex 1.

3.1.1 Methodology of the competency framework construction

In the following the steps of the procedure for the comparison of the procedure model are provided.



1. Literature research of citizen science, data science, scientific literacy and data literacy competencies
2. Definition of the table structure (name, year, author, method, evaluation method, mentioned competences)
3. Filling the table with citizen science, scientific literacy and data literacy competencies
4. Extraction of the competencies into a second table
5. Formation of super categories of the competences in the secondary table
6. Removal of redundancies in the super categories in the secondary table
7. Division of the upper categories into knowledge, skills, and attitudes

8. Identification of interfaces or overlaps of upper categories of citizen science, scientific literacy and data literacy.

9. Creation of the overlaps of upper categories including an activity description “I am aware of …. I do

10. Visualization of the overlaps of Scientific Literacy, Data Literacy and Citizen Science

In the first step, a literature research on necessary competencies of Citizen Science projects was conducted. As a result, the competency fields “data science”, “data literacy”, “scientific literacy” and “citizen science” competencies were identified. More on, the overlapping and similarities of data literacy, scientific literacy and citizen science competencies were identified, and the competencies were collapsed into one map. Due to the smaller significance of data science, data science competencies were not considered in the combined “big map”. In a next step, upper categories were formulated to be able to evaluate the competencies in a next step through expert interviews. The upper categories were created due to the fact that it is not possible to list 200 competencies.

The competencies will be evaluated through expert interviews. Furthermore, through the interview’s insights are gained about other topics as barriers and interventions for integrating citizen science at schools and the needs of students and teachers.

3.2 Competency model description

The following categories are integrated in the big competency map.

- Category of the competency
- Description of the competency
- Operational description of the competency
- Competency level descriptions for
    - Secondary school I, Grade 5-6
    - Secondary school II, Grade 7-10
    - Teachers
- Reference of the competence formulation (curricula or own formulation)
- Learning material example (OER-learning materials)

The whole competency map can be retrieved under: Whole competency map SL, DL, CS .

3.3 Initial Evaluation: Results and Implications

3.3.1 Focus group evaluation

Since there are many categories in the first version of the CS-DL-SL competency set, an expert-driven approach was used to make the competency set more precise and adequate through a participatory approach, where the author had a moderating role and the actors engaged in a dual role of co-researchers and co-subjects (Breu & Peppard, 2001).

Table 10: Participants of the further development of the competency set (own created)

Function	Knowledge area
Professor	Business computer science
Researcher	Industrial design, product design and development
Researcher	Technical expert at fabrication laboratory
Professor	Social technologies, communication, and information management
Researcher	Information systems, competency models

The detailed results of competency allocation can be found in Appendix B: Allocated competencies in the workshop. The following upper-level categories emerged from the competency workshop.

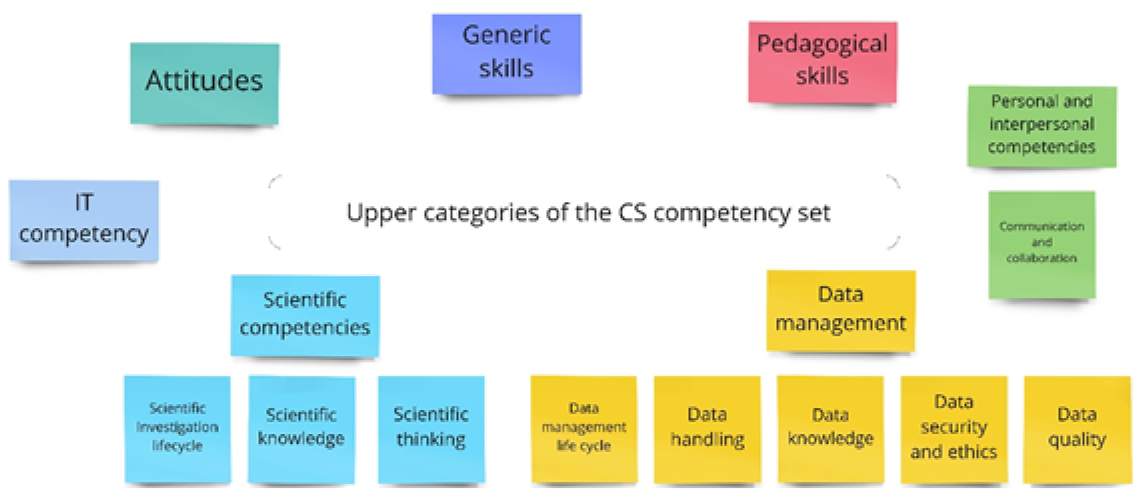


Figure 14: Results of competency clustering through the competency workshop based on the first version of the CS-DL-SL competency framework

3.3.2 Evaluation with teachers

//TODO: Has to be done

3.3.3 Evaluation with practitioners

//TODO: Has to be done

3.4 Competency (Scheme) and Guideline

In this section each partner provides a guideline on how to map the curricula.

Lithuania:
The task of the school is to help the student to develop both general and subject competencies. Although the content of general education in the curricula is quite regulated and the traditional subject system is maintained, it is clear that the content of the subjects must help students to develop general competencies. There is no precise, defined list of competencies. Even internationally, each country draws up a slightly different list of key competences, and schools interpret and adapt it to their needs (Hipkins, 2006, Recommendation 2005/0221 (COD) of the European Parliament and of the Council). Only the main idea is retained - to help students understand how to learn, acquire personal, social, cultural and other competencies, and the names of competencies and their constituent elements - abilities, attitudes - are distinguished according to what is important for students.

Germany:
In Germany, the curricula are relatively strictly defined. The curriculum defines areas of competency, content fields and competency expectations. In the following some definitions are provided (Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen 2019, p.10):

Definition: **Areas of competency**____

> *“Areas of competence represent the basic dimensions of professional action. They serve to structure the individual sub-operations along the subject-specific cores and to clarify access for those involved in the teaching-learning process.”* (Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen 2019, p.10)

Definition: **Content fields**____

> *“Content areas systematize the following with their respective content focus the obligatory and indispensable subjects in comprehensive/secondary school lessons and provide indications for the content-related orientation of teaching and learning*.” (Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen 2019, p.10)

Definition: **Competency expectations**____

"*Competency expectations bring together processes and objects and describe the subject-specific requirements and intended learning outcomes, which are to be bindingly achieved in two levels of progression*" (Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen 2019, p.10)

3.5 Competency Mapping (in progress)

In this section every partner goes through the curriculum and tries to find fitting competencies / competency areas.

Lithuania:

General competences can be defined as follows (General Programs, 2008, Methodological Material, 2010)

- Ability to learn;
- Communication;
- Cognition;
- Social;
- Initiative and creativity;
- Personal.

All general competencies are not isolated, they are related. For example, one of the components of the competence to learn is the ability to overcome learning difficulties, and this ability is included in the scope of personal competence.
General competencies are developed together with essential subject competencies: communication in the mother tongue and foreign languages, mathematics, natural sciences and technology, social sciences, culture and art.

Germany:
To identify citizen science competencies in school curricula, the curricula for physics, chemistry, computer science and geography have been analyzed and the approach was to identify overlappings with citizen science and scientific literacy competencies. In the following the analysis table is provided (Table 2).

// Table is in progress

Found CS competencies in the curricula (Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen 2019c), (Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen 2019a), (Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen 2019b),	**Physics curriculu m**	**Chemistry curriculu m**	**Computer science curriculum**	**Geography curriculum**	**Citizen Science / Scientific Literacy**

(Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen 2019d)					
Reproduction and explanation of expertise		X			
Selection and application of expertise		X			
Ordering and systematization of expertise		X			
Transfer and networking of expertise		X			
Recognition of problems and formulation of questions	X	X			
Observation and perception of (physical / chemical) phenomena	X	X			
Formulation of conjectures & hypotheses on (physical / chemical) questions	X	X			
Carrying out examinations and experiments	X	X			
Organize observations and measurement data and evaluate them in relation to the research question		X			
Using models to illustrate (chemical) phenomena		X			X
Scientific thinking and working - comprehend and constructively question in simple steps of scientific knowledge acquisition		X			
Documentation of experiments in the form of protocols, sketches, diagrams and tables	X	X			
Extract information and data from analogy and digital media offerings, reproduce their key messages, and note the source (information processing).	X	X			X
Presentation of the considerations, facts and work results	X	X			

Fact and situation analysis		X			
Name evaluation criteria and options for action		X			
Weighing up and deciding on options for action		X			
Statement & Reflection	X	X			
Argumentating			X		
Modeling and implementing			X		
Representation and interpretation	X		X		X
Communicate and cooperate	X		X		X
Documenting the work process and results	X		X		
CONTENT FIELDS			X		
Information & Data • Data storage • Data processing • Transfer of data with the help of information systems			X		
Algorithm • Recognizing artificial intelligence • Understanding algorithms and what they do • Engaging with algorithms on textual, formal, pictorial, and playful levels • Understanding systematic processes and how computer science systems work			X		
Formal Languages • Understanding of the communication between human and machine			X		

Informatics, People & Society • Consequences of the interactions of information systems, individuals and society • Social responsibility • Recognition of possible security risks			X		
Gaining knowledge	X	X			
Use experimental and other research methods and models	X				
Critical evaluation of data, research methods and information	X				
Selection of data and information, testing for relevance and reliability	X				X
Evaluation of the hypotheses	X				X
Interpretation of data, (trends, structure and relations)	X				X
Exchange about physical knowledge and its application	X				
Planning, structuring, communicating and reflecting in the team	X				
Visualization of data with linguistic, mathematical and pictorial means of representation	X				X
Description and explanation of the meaning of texts. Evaluation and assessment of empirical models and results	X				
Assessment and evaluation of empirical models and results	X				
Use of physical knowledge to evaluate opportunities and risks in selected examples.	X				
Integration of physical facts into problem contexts	X				

Assessment of the applicability of a model	**X**				
independently use the table of contents, index and coordinates in the atlas for orientation and topographical linkage				**X (5-6)**	
extract information from maps using the legend and the scale bar. information from maps using the legend and scale bar				**X (5-6)**	
gain information from pictures, graphics, climate diagrams and tables thematically related information				**X (5-6)**	
create simple diagrams from series of numbers (in accordance with the learning progress in mathematics lessons)				**X (5-6)**	
extract information relevant to the question from texts and reproduce it.				**X (5-6)**	
describe geographically relevant facts identified on exploratory walks under a narrowly defined question				**X (5-6)**	
work with simple models				**X (5-6)**	
distinguish between pro and con arguments on different, controversially discussed issues				**X (5-6)**	
represent their own or other positions argumentatively coherent				**X (5-6)**	
carry out an exploratory walk under limited questioning				**X (5-6)**	
present the results of their work in an appropriate form using the technical terms				**X (5-6)**	
orientate themselves with the help of maps and other aids directly on site and indirectly				**X (7-9)**	

develop spatial questions, formulate justified assumptions and propose appropriate subject-relevant working methods to answer them				**X (7-9)**	
master the steps involved in acquiring information and knowledge with the help of relevant presentation and work tools (map, image, film, statistical data and text), film, statistical data, graphics and text) to develop different factual contexts and to develop and answer spatial questions.				**X (7-9)**	
apply the working steps for creating map sketches and diagrams, also using electronic data processing systems, in order to present geographical information graphically				**X (7-9)**	
research in libraries and on the Internet in order to obtain information. topic-related information				**X (7-9)**	
obtain information from multimedia offerings and from Internet-based geoinformation services (WebGis or geodata viewers)				**X (7-9)**	
distinguish between general geographic and regional geographic access				**X (7-9)**	
infer from simple models the core geographic statements and the interrelationships of various spatial elements				**X (7-9)**	
present geographic facts using the technical terms. present facts in a logical, clear and coherent manner, in relation to the target audience.				**X (7-9)**	

critically assess the significance of representational and work tools for answering questions and examine their relevance for opening up the spatial reality of life				**X (7-9)**	
grasp media presentations as well as interest-driven interpretations of reality				**X (7-9)**	
critically reflect on the results of their own investigations with reference to the underlying research question and the way they work				**X (7-9)**	
are able and willing to take seriously and weigh up the interests and spatial demands of different groups in the use and design of the living space				**X (7-9)**	
make well-founded judgments, taking into account different perspectives, and argue their case.				**X (7-9)**	
assess concrete measures of spatial design with regard to their contribution to securing or endangering sustainable development				**X (7-9)**	
reflect self-critically on their spatial behavior with regard to the associated consequences				**X (7-9)**	
plan a topic-related survey or mapping, carry it out and present the results in a subject-specific, appropriate and addressee-related manner				**X (7-9)**	
represent in simulated (pro and con) discussions solution approaches to space use conflicts with argumentative support				**X (7-9)**	
use possibilities of democratic influence on spatial processes				**X (7-9)**	
are able to act in an ecologically responsible manner in terms of sustainable management in their own environment				**X (7-9)**	

Table 2: Analysis of school curricula with regard to citizen science competencies

Furthermore, there was an analysis of the content areas from the grades 5-9 of the curricula of the subjects “Mathematics”, “Physics” “Media competency framework” and “Computer science”. The whole version is findable in the Appendix 3: Overview of the analysis of the content areas of curricula

4 Implications and Recommendations

4.1 Implications and recommendations for needed competencies in CS

For citizen science projects citizen science, data literacy and scientific literacy are essential.
A first analysis identified the following four competency areas:

- *Scientific Literacy* (Gormally et al., 2012), (Kembara et al., 2020), (Udompong et al., 2014), (Norris & Phillips, 2003)
- *Citizen Science* (Queiruga-Dios et al., 2020), (Phillips et al., 2018a), (Aivelo & Huovelin, 2020), (Jennett et al., 2016)
- *Data Literacy* (Grillenberger & Romeike, 2018), (Wolff et al., 2016a), (Ridsdale et al., 2015), (Bolhuis et al., 2019), (Pothier & Condon, 2019), (Prado & Marzal, 2013), (Sternkopf & Mueller, 2018), (Mandinach & Gummer, 2013)
- *Data Science* (Donoho, 2017b), (Murawski & Bick, 2017b), (Shirani, 2016), (Sentance, 2017)

By further investigating the concepts and definitions of data literacy and data science, it becomes clear that for the classes from 5-9 rather data literacy and less data competencies are needed as data science competencies are more complex (Shirani, 2016), (Hattingh et al., 2019) and data literacy competencies fit better the purpose for the classes 5-9 (Sapp Nelson, 2020), (Henderson & Corry, 2020b). This is the reason why a combined map of Scientific Literacy, Citizen Science and Data Literacy competencies was created and used for the teacher's questionnaire. Thereby, result a strong connection and possibility to integrate citizen science projects to STEM-subjects although citizen science should not be limited to STEM-subjects in general.

As a first step, the CS concept has been identified as important. In addition, scientific literacy (SL) has been identified as a related concept and is therefore integrated in the literature analysis. Moreover, one important goal of CS projects is to enhance the citizens' SL levels (Levy & Germonprez, 2017). Furthermore, one focus is put on data-related competencies because data quality is considered a significant problem in CS projects (Balázs et al., 2021; Lukyanenko et al., 2016), which should be improved using a fitting competency framework that includes data-related competencies for CS. In addition, data literacy is considered since it is perceived as "an important forerunner to data science and incorporates key skills in identifying, collecting, and analyzing data" (Sentance, 2017, p. 81). Because DS competencies are too complicated for secondary school I, this concept is not considered, and instead data literacy (DL) is integrated into the competency framework.
Therefore, the following competency areas result:

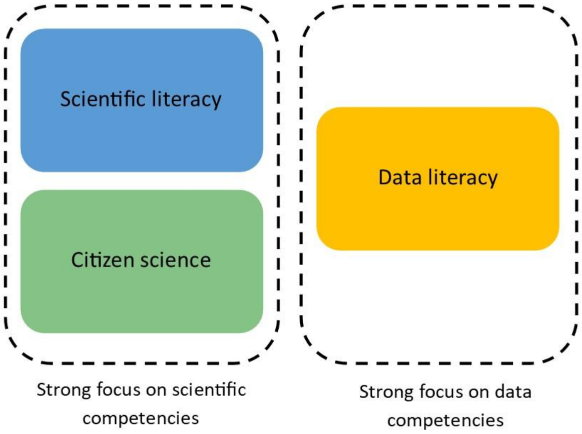


Figure 15: Needed competency areas for undertaking educational CS projects in the IS context

4.2 Implications and recommendations for the construction of a competency framework

The main aim is to describe competencies which are needed for undertaking CS projects and to link them to different curricula. Therefore, the following competency structure is proposed for describing CS-DL-SL competencies and to link them to the curricula:

- **Competency description** describes the competency. A competency can consist of multiple skills, abilities and attitudes.
- **Competency statement** provides an operational statement which can be assessed.
- **Competency classification** describes the main subject of a competency (e.g. Scientific literacy, data literacy, …)
- **Proficiency level** describes levels of mastering competencies. In our context the levels are differentiated by roles
- **Role / level** describes either a role or a level / grade in school
- **Curriculum mapping** links a competency to one or multiple curricula.

Using this scheme helps to specify a competency framework including the links to national / state or school curricula.

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Annex 1 Analysis Planning - Interview Guideline

The following interview guideline was used in each country. The guideline was translated to do the interviews in the local languages.

Interview design
Expert interview, semi-structured

Participants (10 per country, academic experts and school teachers / curriculum designers)

Note: Introduce the key concepts before the interviews. Parts of the presentation of the kick-off meeting can be re-used to introduce the project idea.

The interviewees should agree that the interview is recorded. The interview is anonymized on request.

1.Interviewee background data
Name/Role
Age
Level of education, year of graduation, years of teaching

2.School background data
Country, city:
Level:
Student age
school size

3.CS experience
What is your personal experience in CS projects? Can you describe a good CS project? Have you experienced CS in schools?

4.CS in curriculum
Is there a school, regional or national level curriculum for Citizen Science? How is it implemented? Is it compulsory? In which topics of the curriculum could you see CS kills to fit/to be learned?

5: Data science in the curriculum
Are there data science concepts (e.g. data acquisition, analysis, interpretation, ethics) in the curriculum? In which subjects? If not, where would they fit?

6. Support for the teachers

How are teachers been supported when introducing new topics / subjects? Can they freely adapt the curriculum? Is there education, monetary support or support groups? Is the education ongoing?

7.CS skills

What are useful skills for pupils and teachers (based on https://www.citizenscience.org/wp-content/uploads/2018/11/USERS-GUIDE_linked.pdf)? Do you see additional skills?

Competency	Pupils, which grade?	Teachers
Interest in Science & the Environment Interest in pursuing science and environmental topics, and issues.		
Self-efficacy The extent to which a learner has confidence in his or her ability to participate in (citizen) science		
Motivation Motivation to pursue science and environmental goals such as STEM careers and citizen science project activities.		
Knowledge of the nature of science; understanding of the scientific process and how science is conducted by researchers		
Data Understanding how to gather, analyze, interpret and critically discuss data Understanding how to handle data securely and ethically.		
Skills of Science Inquiry		

Procedural skills such as asking questions; designing studies; handling data; experimenting; argumentation; synthesis;		
Responsible Citizenship Behavior change towards becoming a responsible citizen (e.g. towards environmental or sustainability issues)		
Basic skills technology use; digital literacy		
Social skills Collaboration Communication Critical thinking Reflection		
Additional:		
Additional		

9. Barriers and Interventions

What are the main barriers for incorporating CS in schools = Do you have ideas how to overcome those?

Barrier	Intervention

In case that the interviewee has no idea, typical barriers can be discussed:

- Curriculum barriers: Lack of flexibility, hard to integrate
- Lack of resources (time, budget)
- Lack of skills (of teachers)
- Lack of interest in scientific projects
- Lack of active involvement
- CS is not a school issue, universities should take care of it
- Lack of interest in research / science
- Lack of benefits (e.g. certification)
- Lack of community interest

10. Needs

Do you think that CS could be a helpful practice / tool to be used in grades 5-9 in science subjects?

In which subjects would you see most potential?

What do the schools and educators need?

What would the students need?

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[i] http://www.allyouneediscode.eu/documents/12411/14644/Coding+initiative+report-European+Schoolnet-October2014.pdf/66475be8-cc31-429c-a5cc-32767366c8c2

[ii] http://www.eun.org/fi/resources/detail?publicationID=661

Annex 2: Webster and Watson (2002) concept matrix for guidelines, frameworks and principles for undertaking CS projects

Table 6: Concept matrix for comparing 16 citizen science methodologies, guidelines and approaches according to Webster and Watson (2002) (own created table)

1: (Mäkipää et al., 2020), 2: (Lemmens et al., 2021), 3: (Shirk et al., 2012), 4: (Bonney, Cooper et al., 2009), 5: (European Citizen Science Association & others, 2015), 6: (Herodotou et al., 2018), 7: (Heigl et al., 2020), 8: (Johnson et al., 2014), 9: (Nowak et al., 2021), 10: (Tweddle et al., 2012), 11: (Pocock et al., 2013), 12: (Harris & Ballard, 2018), 13: (U.S. GSA, 2021), 14: (Yadav & Darlington, 2017), 15: (OEAD, 2018), 16: (OEAD, 2021)

Author / Concept	**STEP**	**GUIDELINE**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Participants	**S**	**G**	**X**	**X**		**X**	**X**	**X**	**X**			**X**	**X**	**X**	**X**	**X**		**X**
Project is unachievable without participants		G							X				X		X			
Form a scientist / educator / evaluator /leader team	S					X						X		X				
Recruit participants	S					X						X						
Train participants & choose adequate training	S					X						X	X	X	X			X
Get to know the skill level of participants	S														X			
Involvement of citizens in scientific endeavour Contributors, collaborators, or project leaders (multiple stages)	S	G					X X	X	X			X				X X		
Volunteer participation (active / passive) Active participation of students		G										X				X		 X
Engage volunteers (as initiators of CS)		G						X	X			X			X			
Provide participants feedback and give support	S	G					X		X			X	X		X			

Create a benefit for scientists and participants		G					X		X			X						
Address different interest groups		G				X			X									
Make participants feel part of the team		G										X						
Understand participants motivation and target		G										X			X			
Participant safety		G										X	X					
Pupils can do different tasks in projects and choose them according to their interests	S	G																X
Acknowledge participants and reward volunteers	S	G					X	X				X			X			
Value users and time		G						X				X			X			
CHALLENGES			**X**								**X**						**X**	**X**
Rigid curriculum											X							
Recruiting students																	X	
Presence of the topic											X							
High workload / occupancy of teachers											X							X
Establish the projects long-term (E2)											X							
Lack of finances / sponsoring											X						X	
Time aspect (of teachers)											X						X	
Linguistic / language barriers											X							
Coordination needed with school management											X							
Timeframe for conducting CS projects											X							
(Missing) interest among the staff											X							
Motivation of teachers											X							
Location of schools											X							
Establish contact to schools / finding the “right partner”											X							
Long term duration of projects (motivating the student’s long term)											X							
Errors can lead to extra work for researchers																		X

Lack of recognition and payment of dedicated teachers																		X
PROJECT OUTCOMES	**S**	**G**			**X**	**X**	**X**		**X**			**X**			**X**			
Science	O				X		X											
Socio-ecological systems					X													
Individuals					X													
Observation and experiences	O											X						
Measure outcomes	S					X						X						
Science outcome (e.g. answer research question)	S						X		X			X						
Disseminate results	S					X						X			X			
Publish the results (open access)	S					X			X			X			X			
Publish the results in a comprehensible manner		G				X			X			X			X			
DATA	S	G			**X**	**X**	**X**		**X**			**X**	**X**	**X**	**X**	**X**		**X**
Understanding data needs and being aware of the data lifecycle		G													X			
Accept, edit and display data	S					X						X						
Data collection	S											X	X	X		X		X
Analyse and interpret data	S					X						X		X	X	X		
Data processing	S														X	X		
Visualize data	S											X						
Data storage	S														X			
Develop, refine and test support materials	S					X						X						
Information about CS projects		G			X													
Open science - Make data publicly available	S						X		X									
Data management plan according to European General Data Protection Regulation		G							X						X			

Protect data	S	G																X
Share data	S													X				
Measure and evaluate data quality	S											X			X			
Upload data	S													X				
SCIENTIFIC ISSUES	**S**	**G**			**X**	**X**		**X**	**X**					**X**	**X**	**X**		**X**
Identify question or issue	S				X	X			X					X				
Scientific interest		G							X									
Public interest									X									
Further investigate on youth questions		G												X				X
Scaffold the scientific inquiry process	S							X								X		
PROJECT EVALUATION	**S**	**G**			**X**		**X**					**X**		**X**	**X**			
Evaluation framework		G			X													
Evaluate scientific output, data quality, participant experience and outcomes	S						X					X						
Consider limitations and biases		G					X											
Reflect on learning / experience	S													X	X			
PROJECT SETUP	**S**	**G**					**X**	**X**	**X**			**X**	**X**	**X**	**X**	**X**		**X**
Find a suitable research question	S																	X
Get approval from the supervisors	S														X			
Introduce the project	S													X				
Learn from field guides	S													X				
Observe and sketch specimens	S													X				
Identify question	S											X	X		X			
Execute small trials	S											X						
Check whether CS is a suitable approach	S											X	X		X			

Choose the right citizen science approach	S														X			
Vary the investigation types and topics according to citizens interests		G						X										
Choose an adequate method	S								X									
Open and clear project objectives /aim		G							X			X	X		X			
Cost analysis and funding	S											X			X	X		X
Test and modify protocols	S											X	X					
Planning resources (material, spatial, personnel)	S												X		X			X
PROJECT INFRASTRUCTURE	**S**	**G**			**X**			**X**							**X**	**X**		
Development of mobile application to scaffold data collection projects	S							X								X		
Deployment (thin client /thick client / sensor data processing)	S															X		
Develop project infrastructure and manage project implementation	S				X										X	X		
COMMUNICATION		**G**						**X**	**X**			**X**	**X**		**X**			**X**
Facilitate participation through communication channels (as email notifications)		G						X	X									
Communicate key messages of learning by doing		G						X										
Communicate the doing and being part of the community		G						X										
Clear assignment of tasks		G							X									
Learn the basic terminology in crowdsourcing and citizen science	S														X			
Establish reliable communication with the contact person		G																X
Use accessible language		G										**X**						
PROJECT EXPLOITATION	S											X		X	X			

Share the results with the public (schools /city council / parents/organizations)	S										X		X					
Present to other classes	S												X					
Talk to local citizen scientists	S												X					
ETHICAL AND LEGAL ASPECTS	S	G					**X**		**X**						**X**			**X**
Project objectives must be ethically sound		G							X									
The project must follow transparent ethical principles		G							X									
Project management should consider ethical aspects as inclusion and equality		G							X									
Be sensitive to socio-cultural issues		G													X			
Consider legal and ethical issues as copyright and data sharing agreements		G					X											
Ethical approval before project start	S																	X
Assurance of the implementing, guiding project staff	S																	X
Rights of the persons depicted in pictures		G																X
Copyright and rights of use		G																X
PROJECT IMPROVEMENT	S	G													**X**			
Adapt to cycles of participation.	S	G													X			
Communicate effectively		G													X			
Solicit feedback from your participants	S														X			
Sustain your project funding	S														X			
Evaluate your participants' engagement	S														X			
Build flexibility into your project		G													X			
Know how to end your project	S														X			
SCHOOL SPECIFIC PLANNING	S	G															X	X

Contact schools before there is any concrete project planning	S																	X
Full-day project meeting (e.g. kickoff) with teachers, researchers and students	S																X	X
Take into account the different perspectives and expectations of all participants		G																X
COLLABORATION WITH SCHOOLS	S	G															X	X
Alignment of the timetable with the semester planning of the universities and the annual planning of the schools (e.g. planning in May and June, as this is when planning takes place for the coming school year takes place, consider lecture free periods, exam-intensive periods, school-autonomous days)	S																X	X
Allow time for consultation with or consent from education directors, ethics committees and parents/guardians		G																X
Keep connected to the young people to strengthen their motivation		G															X	
Being aware that students leave school after matura (time planning)		G															X	
Networked cross-thematic issues depend on the school's location and sympathy between teachers		G															X	
Consider non-funding at the application stage to prevent frustration because of rejected proposals		G															X	
Researchers support with funding bodies	S																X	
Communication is the key for success		G																X
Open contact and communication with each other		G																X
Do not underestimate group dynamics		G																X
The level and parts of involvement of children and young people should be clear	S	G																X

Assess from which school level the requirements can realistically be fulfilled by the pupils	S	G																X
Provide local connections to strengthen the motivation of the pupils		G																X
Activation of the different potentials of pupils and teachers through the project		G																X
Let students feel like scientists and support them		G																X
Soften the hierarchy – students and teachers should see themselves as researchers		G																X
Teachers and researchers support pupils to develop their own thinking, autonomy, competency		G																X
Through selected participation methods and procedures, participation can be designed in such a way that pupils participate voluntarily		G																X
Declarations of consent for participation by parents	S																	X
Identifying scope for project work in the curricula	S																	X
Identifying the integration of inquiry-based learning into teaching	S																	X
Use the possibility of elective subjects or a free hour quota for free project work	S																	X
School budget planning	S																	X
Establish projects long-term (contact point for schools, cooperation)	S																	X