# Surrounded by Science

***Learning Paths towards Science Proficiency***

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## Deliverable 5.1

## Impact Assessment Methodology & Instruments

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## Legal Notices

# Executive Summary

Bridging between formal and informal science learning resources to improve science education is a considerable challenge. The Surrounded by Science project is tackling this challenge by developing a unique methodology to assess the learning outcomes of 18 informal STEM (iSTEM) case studies, with the assistance of a digital app, the Science Chaser.

The impact assessment methodology involves the integration of four different research perspectives applied to three iSTEM learning contexts. Each research perspective has a different way of assessing how the iSTEM activities and programmes impact the 6 strands of Science Proficiency for different target audiences. This mixed-method and multi-dimensional research approach is designed to enhance the validity and credibility of the research findings.

Chapter 1 presents the rationale and goal of the deliverable. Chapter 2 presents the theoretical background relating to the six strands of Science Proficiency, the research perspectives, the three iSTEM learning contexts, the case studies, and the need for ecological validity. Chapter 3 presents the assessment tools according to the different research perspectives. Chapter 4 is the conclusion. It presents a summary of the learning contexts, a summary of the tools in each of the first three research perspectives for each strand of Science Proficiency, how the resulting data will provide value to both iSTEM activity designers and researchers, how the assessment of the case studies can contribute to bridging between formal and informal STEM learning, and next steps for the project.

The tools chosen for the impact assessment are discussed in the deliverable and collected in the appendices. These tools include a tracking and timing observation sheet and visitor conversations form for the context-oriented research perspective in the designed environments, as well as self-report questions and the Semantic Differential Emotion Questionnaire (Yonai & Blonder, 2022) for the person-in-context research perspective. Also included are tools to measure the strands of Science Proficiency using the person-oriented research perspective: the Interest Questionnaire (Linnenbrink-Garcia et al., 2010), the Nature of Science Questionnaire (Conley et al., 2004), the Authenticity Questionnaire (Boll, 2013), the Science Identity Questionnaire (Vincent-Ruz & Schunn, 2018), and the Self-Perception in Science questionnaire (OECD, 2016). Two strands of Science Proficiency will be measured by questions and/or visual representation (such as content maps) tailored by the project staff to assess learner knowledge and reasoning for specific activities and programmes. The Daily Activity in Science Questionnaire (OECD, 2016) will be used in the everyday-life research perspective.

An important aspect of this deliverable is a detailed example of the everyday-life research perspective in Chapter 3. This example, to be implemented in the upcoming research cycle (2022-3), combines formal and informal science learning resources in a long-term (2-month) learning pathway. Other examples of this research perspective, with similar learning pathways, will be implemented in the second research cycle (2023-4).

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# 1 Introduction

> "Schools cannot act alone, and society must better understand and draw on the full range of science learning experiences to improve science education broadly."
>
> From *Learning Science in Informal Environments: People, Places and Pursuits*. National Research Council, 2009.

## *1.1 Rationale and goal*

Combining formal and informal science learning resources to improve science education broadly is a considerable challenge. The Surrounded by Science project brings together a variety of stakeholders -- science education research experts, science centres and museums professionals, outreach and informal science activities providers, strong user communities, and policymakers across Europe -- to design and develop a systematic assessment methodology that will analyse the impact of informal school science learning activities.

Central to the project's vision of bridging the gap between these two worlds of science learning is the development of connected science learning ecosystems, where young people can encounter a wide range of learning experiences with the support of adults and peers. This vision requires that science educators and organisations think beyond the boundaries of their own institutions, in order to provide connected learning opportunities and to address inequalities in a way that more isolated efforts cannot.

In order to implement this vision, the project will conduct 18 in-depth case studies of informal STEM (iSTEM) activities and programmes from different learning contexts, with different audiences, using different research perspectives, and with the help of the digital app, the Science Chaser, that is developed in WP3.

Based on this rationale, the project will address the following guiding question: **How can informal STEM (iSTEM) learning activities contribute to the development of science learning in formal science settings, and vice versa?**

Three sub-questions will also be addressed:

a. What are the <u>outcomes</u> of these iSTEM activities and programmes in terms of science proficiency?

b. What <u>design features</u> of the iSTEM activities and programmes foster science proficiency?

c. How might the iSTEM activities be used to <u>bridge</u> between formal and informal STEM learning?

In deliverable D2.3, over 60 iSTEM activities and programmes were investigated and presented. From this repository, 18 case studies were selected. The goal was to have as diverse a selection as possible (in terms of different learning contexts, activity types, activity providers, STEM topics, and key design characteristics) and to choose cases that are practical in terms of data collection. See Section 3.1 in D2.3 for details.

The goal of this deliverable is to present the methodology and specific tools to collect and analyse data in these case studies that will productively address the research questions presented above.

## 1.2 Overview

This deliverable focuses on the theoretical background for the methodology and then reports on the tools that have been chosen. After this first introductory chapter, Chapter 2 provides the theoretical background for each of the six strands, the four research perspectives, the three learning contexts and case studies, and the methodology criteria and guidelines:

- The 6 strands of Science Proficiency. The assessment of the case studies will be conducted in light of the 6 strands of Science Proficiency. These strands are delineated by the National Research Council (2009) as "a framework that articulates science-specific capabilities supported by informal environments." In Section 2.1, the theoretical background for each of these strands is presented.

- The 4 research perspectives. In each case study, the 6 strands will be assessed using different research perspectives, organized in increasing "grain size": the context-oriented perspective (focusing on behaviour of the participant/visitor in the context), the person-in-context perspective (focusing on the experiences of the participant/visitor with a specific activity), and the person-oriented perspective (focusing on the effectiveness of the activity using pre-post measures).

  The value of using different research perspectives to assess the same strand variables is *triangulation*, i.e., the use of multiple methods – both quantitative and qualitative tools -- to measure the same outcomes. In practical terms, this mixed-methods research approach helps to enhance the validity and credibility of the research findings (Bhandari, 2022). The fourth research perspective (the everyday-life perspective) studies science learning in learning pathways. The characteristics of each of these research perspectives will be presented in Section 2.2.

- The 3 learning contexts and case studies. The project has identified 3 contexts of iSTEM activities: outreach programmes, designed environments, and technology- and media products. In Section 2.3, the characteristics of each of these learning contexts are delineated. In addition, all case studies that have been chosen to represent one of the 3 learning contexts will be investigated by pre-assigned research perspectives.

- Methodology criteria and guidelines. The methodology chosen in this deliverable is aligned with accepted practice in the world of informal science learning – being careful to maintain the ecological validity of the studies. In addition, the tools are valid and reliable, as determined by the literature and the choice of tools are well-adapted to different audiences, i.e., learners of different ages, family groups, and media users. Chapter 2.4 provides these methodology criteria and methodology guidelines.

In Chapter 3, the specific tools chosen for the impact assessment of the case studies are presented, according to the different research perspectives. The Science Chaser, a digital app that is being developed in the project, will serve as the main platform for using these tools to assess the iSTEM activities and programmes in the case studies.

Chapter 4 presents a summary of the learning contexts, a summary of the tools in each of the first three research perspectives for each strand of Science Proficiency, how the resulting data will provide value to both iSTEM activity designers and researchers, how the assessment of the case studies can contribute to bridging between formal and informal STEM learning, and next steps for the project.

The deliverable ends with the appendices in which each of the chosen tools are presented.

# 2 Theoretical background

## *2.1 The six strands of Science Proficiency*

The theoretical basis of the research methodology of the Surrounded by Science project comes from the 6 strands of Science Proficiency. These strands are described by the National Research Council (NRC, 2009) and represent the desired outcomes of the iSTEM activities in the project. It is important to note that these strands are to be viewed as mutually connected, using the metaphor of strands in a rope. They are:

1. Being Interested in and Excited by Science,
2. Understanding Scientific Content and Knowledge
3. Engaging in Scientific Reasoning
4. Reflecting on Science
5. Using the Tools and Language of Science
6. Identifying with the Scientific Enterprise (Science Identity)

The definition of these strands (NRC, 2009) and the key research concepts underlying each of them, as understood in the project, are presented in Table 2.1.

**Table 2.1**. *Description of the 6 strands, as delineated by the NRC (2009), and the corresponding research concepts, as understood by the Surrounded by Science project.*

| Strand | NRC Description | Research Concepts |
|---|---|---|
| 1. Being Interested in and Excited by Science | Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world. | Interest<br>Engagement |
| 2. Understanding Scientific Content and Knowledge | Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science. | Factual knowledge<br>Conceptual knowledge<br>Procedural knowledge |
| 3. Engaging in Scientific Reasoning | Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world. | Understanding explanations and arguments |
| 4. Reflecting on Science | Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena. | Nature of Science (NOS): understanding how science knowledge develops |
| 5. Using the Tools and Language of Science | Participate in scientific activities and learning practices with others, using scientific language and tools. | Scientific language<br>Scientific tools<br>Authentic science |
| 6. Identifying with the Scientific Enterprise | Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science. | Science identity<br>Self-perception in science |

It is important to note that while strands 2, 3, 4, and 5 were originally defined in relation to formal science learning in schools (NRC, 2007), strands 1 and 6 were added because they are especially significant to informal science learning (NRC, 2009):

> "Strand 1, while important for learning in any setting, is particularly relevant to informal learning environments, which are rich with everyday science phenomena and organized to tap prior experience and interest. Strand 6 addresses how learners view themselves with respect to science. This strand speaks to the process by which individuals become comfortable with, knowledgeable about, or interested in science. Informal learning environments can play a special role in stimulating and building on initial interest, supporting science learning identities over time as learners navigate informal environments and science in school. The strands serve as an important resource from which to develop tools for practice and research. They should play a central role in refining assessments for evaluating science learning in informal environments." (NRC, 2009)

In the Surrounded by Science project, we look at these strands as "the starting point" of our assessment work. The related research concepts are useful in the search for appropriate assessment tools, as will be discussed in the remainder of this chapter and in Chapter 3 of this deliverable.

### 2.1.1 Strand 1: Being interested in and excited by science

"Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world." (NRC, 2009)

Two variables will be assessed for this strand: interest and engagement. Interest is a psychological state that, in later phases of development, is also a predisposition to reengage content that applies to in-school and out-of-school learning and to young and old alike. The level of a person's interest has repeatedly been found to be a powerful influence on learning (Renninger & Sue, 2021).

Interest has also been found to influence attention, goals, and levels of learning. The Four-Phase Model of Interest Development (Hidi and Renninger, 2006) builds on and extends empirical studies of interest and learning, and proposes these four phases of interest development:

- **Triggered- Situational Interest** - a psychological state of interest that results from short-term changes in affective and cognitive processing
- **Maintained Situational Interest –** a psychological state of interest that is subsequent to a triggered state, involves focused attention and persistence over an extended episode in time, and/or reoccurs and again persists
- **Emerging Individual Interest** - a psychological state of interest as well as to the beginning phases of a relatively enduring predisposition to seek repeated reengagement with particular classes of content over time
- **Well-Developed Individual Interest –** a psychological state of interest as well as to a relatively enduring predisposition to reengage with particular classes of content over time

Engagement can be understood as voluntary, active, and prolonged participation in whatever STEM phenomenon the learner is involved (Humphrey & Gutwill, 2005). Three dimensions of engagement include *behavioural engagement* (whether or not learner behaviours are related to completing the task), *cognitive engagement* (whether or not the learner's thought processes and attention are directed towards meaningful processing of information involved in completing the task) and *affective engagement* (whether or not the learner's emotions are positive and high arousal rather than negative and low arousal) (Fredricks, et al., 2004).

### 2.1.2 Strand 2: Understanding scientific content and knowledge

"Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science." (NRC, 2009)

While learning any topic, learners can acquire different types of knowledge. Moreover, in the research literature, not only are different types of knowledge distinguished but also different qualities, such as level (surface or deep), structure (isolated elements or structured knowledge) and others (de Jong & Ferguson-Hessler, 1996). The project adopts the framework of different types of knowledge, based on a revision of Bloom's taxonomy, (Krathwohl, 2002):

(1) Factual knowledge: the basic elements that students must know in order to be acquainted with a discipline or to solve problems in it. This includes knowledge of terminology as well as knowledge of specific details and elements.

(2) Conceptual knowledge: the interrelationships among the basic elements within a larger structure that enable them to function together. This includes knowledge of classifications and categories; knowledge of principles and generalizations; and knowledge of theories, models, and structures.

(3) Procedural knowledge*:* how to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods. This includes knowledge of subject-specific skills and algorithms, knowledge of subject-specific techniques and methods, and knowledge of criteria for determining when to use appropriate procedures.

(4) Metacognitive knowledge: knowledge of cognition in general as well as awareness and knowledge of one's own cognition. This includes strategic knowledge; knowledge about cognitive tasks, including appropriate contextual and conditional knowledge; and self-knowledge.

Not all types of knowledge are equally important and represented in iSTEM activities. Therefore, only the first three types will be tested in the framework of the project, namely: (1) factual knowledge, (2) conceptual knowledge (with less or no attention to the knowledge of classifications and categories), and (3) procedural knowledge only for specific activities (e.g., a workshop on using a specific piece of equipment).

The existence of different types of knowledge means that the ways to check this knowledge can and should be different. For example, to check a deeper and more structured level of conceptual knowledge, a task to create a concept map can be used, since this tool shows relationships between concepts in a structured way. For each case study, a tailored assessment will be developed, based on the nature of the activity, its goals, domain, and target groups.

### 2.1.3 Strand 3: Engaging in scientific reasoning

“Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.” (NRC, 2009)

Being able to engage in scientific reasoning is a critical but complex aspect of science proficiency. Scientific reasoning is seen as an ability of students to explain a phenomenon, a situation, consequences, solutions, etc., using logical arguments based on science (and/or technology). In this regard, reasoning should be assessed via instruments asking for such explanations, like open-ended questions or logical schemes. This strand is assessed together with Strand 2 (Understanding scientific content and knowledge) via a shared set of questions. By connecting these questions to the knowledge questions, we can make use of the same case or contextual information.

One of the ways to ask for explanations is to use questions utilizing the What if? (and why?) format (Swaak, de Jong, 2004). In this format, we present students with a certain state or scenario and ask them to explain what will happen if we intervene in a specific way. For instance what will happen to the velocity of the cart on our ramp if we put an extra doll in the cart? And why is this happening? More examples for this strand can be found in Chapter 3.

### 2.1.4 Strand 4: Reflecting on science

“Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.” (NRC, 2009)

The learning outcome to be assessed for this strand is the nature of science (NOS). This term refers to students *reflecting on science and technology as ways of knowing*. According to Conley (2004), a person’s belief about the Nature of Science can be measured on four dimensions: (a) the source of scientific knowledge (from an authoritative to an evidence-based approach), (b) how certain is scientific knowledge (from very certain to tentative), (c) the development of scientific ideas over time (from no development to a development of ideas), and (d) the role of experiments and the use of data to support arguments (from not important to important). The nature of science is that it is evidence-based and tentative. In this enterprise, scientific ideas develop over time and the role of experiments and the use of data to support arguments are important (Conley, 2004).

This learning outcome is “a critical component of scientific literacy” because it enhances students’ understandings of science concepts and enables them to make informed decisions about scientifically-based personal and societal issues (NSTA, n.d.).

### 2.1.5 Strand 5: Using the tools and language of science

“Participate in scientific activities and learning practices with others, using scientific language and tools.” (NRC, 2009)

Using the tools and language of science relates to the ability of participants to properly operate scientific instruments or equipment, and to use scientific terms and concepts in the right, authentic way. It has been known that using scientific terms when talking about science not only demonstrates the knowledge of these terms but also helps students to make sense of the phenomena (Lemke, 2004). Moreover, following discourse rules used in writing scientific papers contributes to science learning (Prain, 2006).

Using the tools and language of science also relates to ‘‘authentic science’’, i.e., experiencing science as it really is, rather than as a mythic, textbook notion of science (Martin et al., 1990). The conceptual foundations of authentic learning are linked to the theory of situated cognition, from a study of highly successful learning interactions that occurred in actual working environments (Brown et al., 1989). Science authenticity can be experienced in a research laboratory, whether in a school or in a research institute.

Authentic science can be experienced in informal science learning settings. The literature includes many examples of such experiences, with various benefits for learners—for example, in contributing to students' engagement in and motivation to learn science (Cook, et al., 2020). Another well-established benefit is in better communicating the nature of science and science technology, and society issues. A scientist in an authentic setting can best communicate these issues to teachers and students. Additionally, perceiving and experiencing science authentically and being able to engage in authentic scientific activities can eventually lead a student to being a part of the scientific community (e.g., Rethman, et al., 2021), which is part of the following strand of science identity.

### 2.1.6 Strand 6: Identifying with the scientific enterprise

"Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science." (NRC, 2009)

Identity is defined as a "general sense of self with reference to groups or particular content" (Renninger, 2009: 109). As such, identity formation and enactment are inherently social in nature for they require the participation of meaningful others. Accordingly, it can be argued that experiences in science-related contexts, both formal and informal, inform individuals' understandings of self as a 'science person'.

Science education scholars have studied science identity with the analytical frameworks proposed by Carlone and Johnson (2007) and Hazari et al. (2013). Common to these frameworks is the conceptualization of science identity as a multi-dimensional construct. Specifically, Carlone and Johnson's (2007) framework suggests that science identity is made up of 3 components:

- ***Competence*****.** This refers to having scientific knowledge as well as the motivation "to understand the world scientifically" (Ibid: 1190).
- ***Performance****.* This refers to being able to demonstrate scientific knowledge to others.
- ***Recognition****.* This refers to both self-recognizing as well as meaningful others recognizing one as "a science person".

Much of the extant theory and research on this concept has focused on understanding antecedents and outcomes of science identity formation and enactment at school and tertiary levels. Taken together, this body of research has identified both **state-like factors**, such as *self-efficacy* (i.e., competence and performance), *interest* and *recognition* as the main factors that shape the formation, development, and sustenance of science identity, as well as **trait-like factors**, such as *demographic differences* (e.g., gender, race, ethnicity) that may condition science identity trajectories.

## 2.2 Research perspectives

The Surrounded by Science project is committed to assessing the iSTEM activities in the case studies via four research perspectives. Each of these research perspectives focuses on different but overlapping goals, using different tools, in order to assess learning via iSTEM activities.

1. **Context-oriented perspective.** Insights regarding the characteristics of the context that trigger attention and interaction, based on *tracking* the behaviour of the users.
2. **Person-in-context perspective.** Insights regarding the interaction and experiences of users, based on a *short self-report questionnaire* related to their experiences, their appreciation and accessibility of the activity, perceived learning, and motivation to participate in similar and other science activities.
3. **Person-oriented perspective.** Insights about the outcomes that iSTEM learning activities have regarding the six strands of science proficiency, based on *questionnaires and interviews* (e.g., regarding factual, conceptual and procedural knowledge), given before and after the iSTEM activity. Only in this perspective, it will be possible to suggest causality, i.e., collect data that demonstrates that a given activity is responsible for leading to a given outcome for a given target audience.
4. **Everyday-life perspective.** Insights based on the everyday interests and engagement of users in science activities (e.g., watching a documentary, reading a science magazine, or visiting a science-related website), based on *periodic self-report diaries*.

It is important to note that the first three perspectives can be used to assess the same iSTEM activity or programme, i.e., focusing respectively on the behaviour of the learner in the context of the activity (in the first perspective), on the experience of the learner (in the second perspective), and the objective outcomes of the iSTEM activity or program (in the third perspective). In contrast, the fourth perspective focuses on the learner's behaviour, self-report, and learning outcomes that result from navigation through a wide variety of different iSTEM activities and programmes.

The Surrounded by Science project is oriented to develop and assess the Everyday-life perspective, because it represents the very concept of "surrounded by science". For this reason, the theoretical background of this fourth research perspective is presented in more detail below.

The fourth research perspective is based on the concept of a connected science learning ecosystem, as illustrated in Figure 2.1, where youth may encounter a wide range of learning experiences and be supported by adults and peers in ways that could lead to future opportunities in personal, academic, professional, and civic realms. Learners can negotiate their learning through "learning pathways" (Sotiriou & Bogner, 2017) that connect their learning across the many contexts, for example, home, school, community organisations, science centres and museums, games, web and social media where learning may occur.

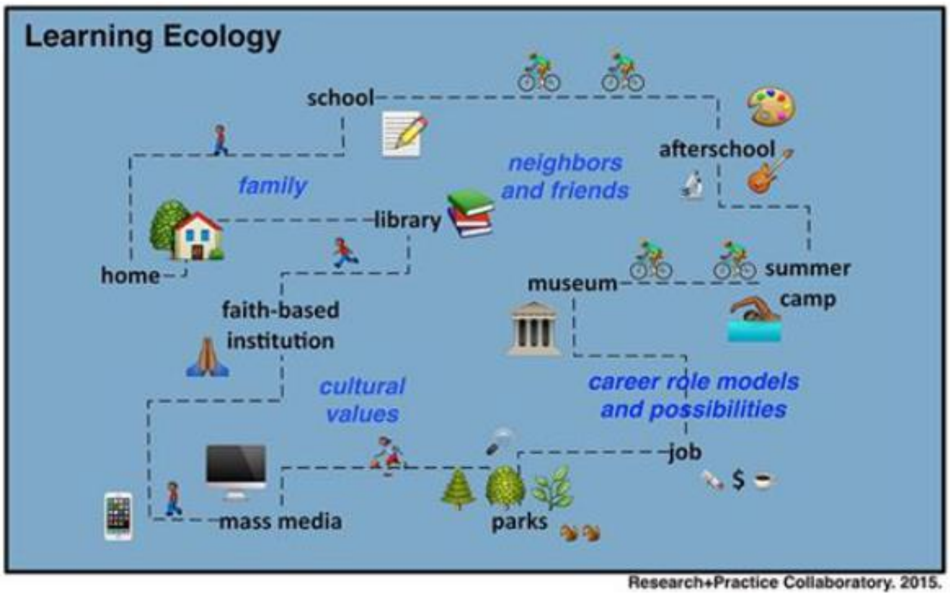



**Figure 2.1.** *A connected science learning ecosystem (Bevan, 2016).*

Each of the many learning contexts in a connected science learning ecosystem can be understood as lying on a continuum, as presented in Figure 2.2. The far right side of the continuum represents learning contexts that are characterized by high learner choice, low consequence assessment, and experiences structured by the learner; these contexts are usually identified as out-of-school. The far left of the continuum represents learning contexts that are characterized lower learner choice, high consequence assessment, and experiences not structured by the learner; these contexts are usually identified as school settings. Of course, hybrid learning contexts can exist between these two extremes, where these characteristics coexist in moderate degrees.

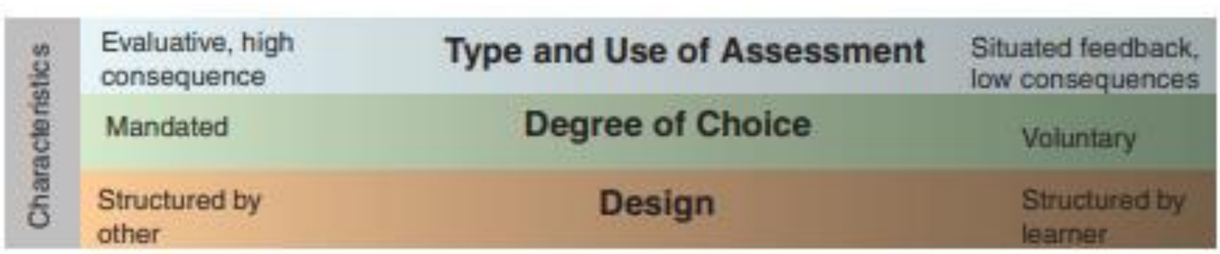



**Figure 2.2.** *Continuum of learning context design. Taken from NRC (2009), p. 47.*

Central to this continuum is the concept of free-choice learning, defined as learning that is "*intrinsically motivated and largely under the choice and control of the learner*" (Falk & Dierking, 2000; Falk, 2001). Different learning contexts have different degrees of free-choice learning.

The of the everyday-life perspective, effectively integrates the three other research perspectives of the evaluation. It also covers the whole range of the three learning contexts, different activity or programme timeframes, an in-depth study of all six strands of Science Proficiency, and an extensive use of the Science Chaser.

## 2.3 The learning contexts of the case studies

The Surrounded by Science project identifies iSTEM learning as the outcome of the individual's engagement with activities in three learning contexts. These science learning contexts are characterised by diversity, redundancy, and local adaptations and can contain a wide variety of activities, across a range of institutions and places, allowing individuals different and multiple ways to engage with science. The activities in these learning contexts can be part of a larger programme or can be stand-alone activities. Therefore, within each context, we can make a distinction between programmes (a coherent set of activities that belong together) and activities (see Table 2.2).

**Table 2.2**: *The three learning contexts of iSTEM activities, along with the forms of learning supported by each context, their educational objectives and examples.*

| Contexts | Supported Forms of Learning and Educational Objectives | Examples of Settings | Examples of Activities |
|---|---|---|---|
| **Scientific Outreach Programmes** | Guided Inquiry (focus on scientific content knowledge, scientific reasoning skills, and reflection on science and scientific processes) | Universities, science museums, schools, community centres (non-formal education) | Research Facilities<br>Outreach Programmes<br>Science Clubs<br>Contests<br>Citizens Science Projects<br>Summer Schools<br>Science Fairs |
| **Designed Environments** | Contextualised Learning (focus on motivation, interest in science, and interest in pursuing a science-oriented career) | Zoos, botanical gardens, science museums, etc. (non-formal education) | Real-life and virtual visits to exhibitions, zoos, botanical gardens, museums and science centres |
| **Technology and Media Products** | Incidental and Free Choice Learning | Digital settings, such as websites and podcasts, used at home or during free time (informal education) | Website<br>Videos / YouTube<br>Simulations<br>Games<br>Apps |

In deliverable D2.3, based on an analysis of over 60 iSTEM activities and programmes, the success criteria for each of these three learning contexts were derived. See Table 2.3 for an overview.

**Table 2.3**. *Success criteria for each learning context (from D2.3, Inventory of Activities and Selected Case Studies)*

| Outreach programmes | Designed environments | Technology and media products |
|---|---|---|
| 1.Connection to real life | 1. Connection to real life | 1. Accessible/ easy to use |
| 2. Choice of topic | 2. Choice of topic | 2. Connection/relevance to real life |
| 3. Encouraging curiosity/ questioning/ inquiry | 3. Encouraging curiosity/ questioning/ inquiry | 3. Encouraging curiosity/ questioning/ inquiry |
| 4. Personal experience/ interest-based | 4. Combining visual, audial and kinaesthetic information and activities | 4. Visually attractive (design) |

| | | |
|---|---|---|
| 5. Interactivity | 5. Active involvement/ interactivity | 5. The way of presenting information (for media products) |
| 6. Collaboration/ dialogue with peers | 6. Visually attractive materials | 6. Interaction with the audience/ active engagement (for media products) |
| 7. Age- and ability-appropriate language and tasks | 7. Authentic materials | |
| | 8. Collaboration/ family learning | |
| | 9. Age- and ability-appropriate language | |

For each case study, we decided which research perspective will be used in the assessment implementation. Table 2.4 gives the overview.

**Table 2.4**. *The case studies within the three learning contexts and their respective research perspectives. More details about each case study can be found in the D2.3 deliverable. The asterisk (*) means that the activity is a part of the 4$^{th}$ research perspective and learning pathway described in Section 3.4.*

| | **Context-oriented perspective** | **Person-in-context perspective** | **Person-oriented perspective** |
|---|---|---|---|
| **Outreach programmes** | 1. Maker space<br>2. Master class | 1. Chemistry escape room<br>2. The community of the beach<br>3. Maker space<br>4. Master class<br>5. Observation nights *<br>6. We came back to look at the stars | 1. Chemistry escape room<br>2. The community of the beach<br>3. Observation nights *<br>4. We came back to look at the stars<br>5. Master class<br>6. SEM |
| **Designed environments** | 1. Corporea<br>2. Nordhorn zoo<br>3. Pedra do Sal Environmental Interpretation Centre<br>4. Vlinderfabriek | 1. Corporea<br>2. Nordhorn zoo<br>3. Touch tank and " A parte que Fica" Exhibition<br>4. Tutti insieme! (All together!)<br>5. Vlinderfabriek<br>6. Pedra do Sal Environmental Interpretation Centre | 1. Touch tank and " A parte que Fica" Exhibition<br>2. Tutti insieme! (All together!) |
| **Technology and media products** | 1. Davidson Institute's website<br>2. MOOC about recreational math | 1. Galileo museum *<br>2. MOOC about recreational math<br>3. Roger Penrose's models * | 1. Galileo museum *<br>2. The mystery in the forest of Østmarka<br>3. VIRGO experiment * |

## 2.4 Ecological validity and methodological guidelines

The tools chosen for the case studies need to have high levels of reliability and validity. We have decided to choose existing tools, in order to make sure that they have a high reliability. The same tools also need to have ecological validity, as described below:

> "Assessments should fit with the kind of participant experiences that make these environments attractive and engaging.... *Any assessment activities undertaken in informal settings should not undermine the features that make for effective learning there* (Allen, 2002; Martin, 2004)…. Before drawing conclusions about whether the informal experiences have led to particular outcomes, researchers and practitioners should ask themselves: Are the assessment activities similar in relevant ways to the learning activities in the environment? Are the assessments based on the same social norms as those that promote engagement in the learning activities? Overall, is it clear that learners in a setting have had ample opportunity to both learn and demonstrate desired outcomes? Without such clarity, it is difficult to make fair inferences about what has been learned or the effectiveness of the environment for promoting learning.... Informal environments for science learning are characterized by a flexibility and openness to changes in the communities, societies, and cultures of which they are a part. *In order to do justice to both informal environments and those served by them, efforts to identify, measure, and document learning should be expansive enough to accommodate the full range of what and how they may help people learn*."
> (NRC, 2009. Emphasis added)

In this regard, the following methodological guidelines are useful (based on Solis, Hutchinson & Longnecker, 2021):

1. Provide visitors with a friendly environment for assessment. The atmosphere should be that the educational programmes (and not the visitors) are being evaluated.
2. Word questions such that they are clear, non-threatening, short, and unambiguous.
3. Pilot the tools and pay attention to any discomfort of visitors. Discard or modify the method, if signs of discomfort are detected.
4. Modify the questionnaire if needed.
5. Matched pre-post responses allow for direct pre-post comparison, but may also "cue" visitors; depending on available time, number of respondents and needs, consider alternatives, such as splitting samples. One solution to this situation is to include control groups that also take the same pre-post questionnaires.

# 3 Tools

In this chapter, we present the various tools to be used in the case studies to assess the iSTEM learning outcomes, beginning with the Context-Oriented Perspective (3.1), the Person-In-Context Perspective (3.2), followed by the Person-Oriented Perspective (3.3). The same tools will be appropriately selected and combined for the Everyday-Life Perspective, as described in Section 3.4, where the use of the Science Chaser app is also illustrated.

## *3.1 Tools for the context-oriented perspective*

The Context-Oriented Research Perspective provides insights regarding the *characteristics of the context that trigger attention and interaction*, based on tracking the behaviour and the language of the users. The main strand to be assessed will be Strand 1 (Being Interested in and Excited by Science). However, evidence of learner outcomes in the other strands may be gained through the collection of the conversations of the participants/visitors.

The observational and qualitative tools to be used to assess the strands in this research perspective apply to the designed environments and the media programmes, which will be presented next.

### 3.1.1 Designed environments

In designed environments approached from the context-oriented perspective, learner interest and engagement (strand 1) in different exhibits in an exhibition will be assessed by (a) observations of how frequently visitors visit each exhibit and for how long, as well as (b) observation of visitor behaviour at the exhibits.

The observation will include two complementary approaches. The first is to document the visitors' frequency and duration (attractiveness and holding power) via "tracking and timing" (TT) studies, and the second is to document the behaviour of the visitor according the three aspects of interaction of the participants/visitors with the activity (hands-on, minds-on, and emotions-on (Yonai & Blonder, in press)).

Tracking and timing studies will be conducted by collecting outcome variables for the exhibits in an iSTEM exhibition: exhibit attraction power and holding power, as defined below (Lanir et al., 2017):

- Attraction power indicates the relative amount of people who have stopped in front of an exhibit during their visit. It is calculated by dividing the number of people who stop, by the total number of people who have visited the museum. This measure provides us with an initial idea of the power of attraction of the exhibit.

- Holding power measures the average time spent in front of an exhibit. It is calculated by summing up the time a visitor spent in front of a specific exhibit. This measure provides us with an initial idea of the power of an exhibit to hold the interest of a visitor.

This data will then be plotted on a graph, to identify those exhibits that had high attraction power and high holding power, low attraction power and high holding power, high attraction power and low holding power, and low attraction power and low holding power. See Figure 3.1 for an example.

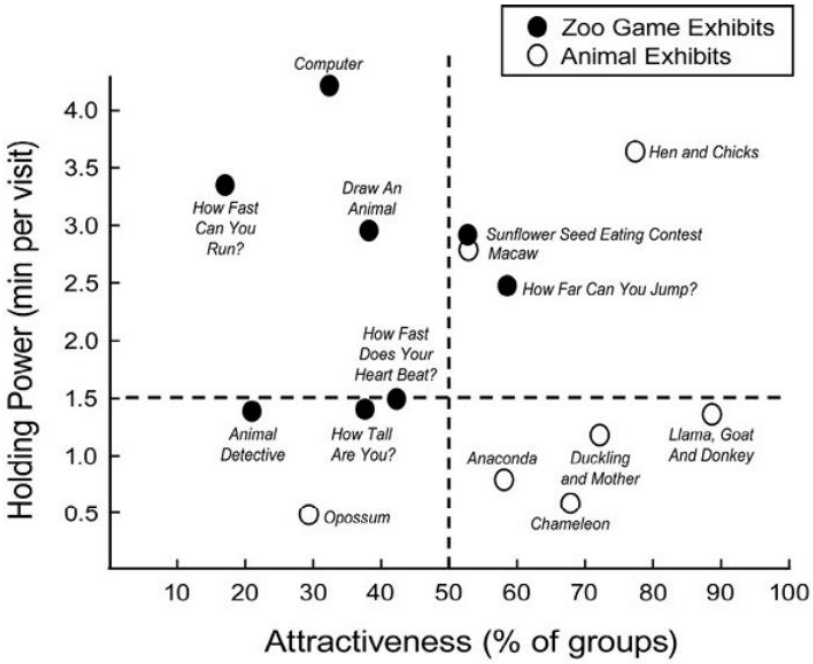



**Figure 3.1**. *A scatter plot indicating the rating of various zoo exhibits, in terms of attractiveness and holding power. The data show that the animal exhibits had high attractiveness but low holding power, while the interactive animal exhibits had relatively high holding power and low attractiveness (Rosenfeld, 1982).*

In addition, from this data we will calculate two other variables that help to characterize and compare exhibitions as a whole: the sweep rate index (SRI) and the percentage of diligent visitors (%DV), as defined by Serrell (2020):

- Sweep rate index (SRI) is calculated by dividing the exhibition's size in square meters by the average total time spent there for a tracked sample of casual visitors. A lower sweep rate means that visitors spent more time in the exhibition and were engaged in more learning-related behaviours.

- Diligent visitors (%DV) is the percentage of visitors in the tracked sample who stopped at more than one-half of the exhibit elements in the exhibition. Higher percentages of diligent visitors mean that more people were paying attention to more exhibits, and fewer exhibit elements were being ignored, skipped, or missed.

When each exhibition is plotted against these two variables, conclusions about visitor behaviour can be made, based on the 5 zones where the *exhibits* are located on the graph. For example, Figure 3.2 shows a graph of these two variables for 65 exhibitions.

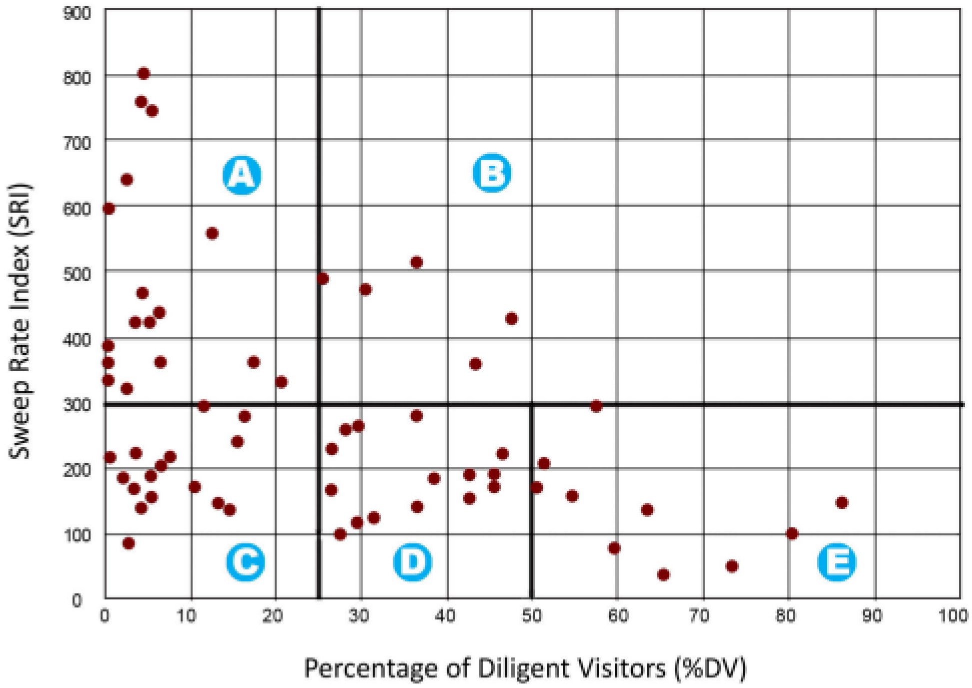



**Figure 3.2**. *This graph gives a visual representation for "thorough use" of different exhibitions by plotting the aggregation of SRI and %DV data. In this graph, each dot represents an exhibition. The least-thoroughly used exhibitions are in the upper-left Chapter (Zone A) – high sweep rate and low percentage of diligent visitors -- while the most-thoroughly used exhibitions are in the lower-right Chapter (Zone E) – low sweep rate and high percentage of diligent visitors (Serrell, 2020).*

Observers for the tracking and timing (TT) studies will be instructed to create data collection forms that (a) specify the relevant observational data: date, time, name of the observer, visitor's gender, visitor type (adult only, child only, adult-child), and approximate age; and (b) provide columns to write in each exhibit visited and the time of visitor entry and the time of departure from the exhibit.

Other observers will document the behaviour of visitors according the three aspects of participant interaction listed above (hands-on, minds-on, emotions-on), either as onlookers or as participant-observers. Onlookers try to remain inconspicuous so as to avoid influencing the participant's behaviour. Participant-observers adapt a level of involvement that is appropriate for the situation. For example, a staff member might enroll in an outreach program, in order to closely observe participant behaviour and participant conversations (Diamond et al., 2016).

STEM engagement in museums can be understood as voluntary, active, and prolonged participation in whatever STEM phenomenon the learner is involved. Engaged visitors take pleasure in "observing, playing, investigating, exploring, collaborating, searching, and speculating" (Humphrey & Gutwill, 2005). In assessing for visitor engagement with exhibits, we will use the engagement scale presented in Figure 3.3).

| | |
|---|---|
| 1. Minimal/Glance | Visitor stops, pauses briefly, and glances at one or more elements, but demonstrates no apparent interest in any particular element or information. |
| 2. Cursory | Visitor stops, watches/views elements briefly in a cursory way, perhaps casually points to something, and glances at text panels, but demonstrates no apparent interaction with the interactive. |
| 3. Moderate | Visitor stops, views several elements of the interactive with apparent interest, reads some text, and appears somewhat engaged and focused. |
| 4. Extensive | Visitor stops, views most elements of the interactive very intently; reads some text and appears very engaged and focused. |

**Figure 3.3.** *Engagement scale to assess visitors' engagement with exhibits (Falk & Holland, 1991).*

Observers will use this scale to assess to what degree visitors are engaged in the exhibits, i.e. from a minimal glance to extensive involvement, as described above. In concert with the time and tracking data, as well as analysis of visitor conversations at the respective exhibits (e.g., what questions do they ask and how do they try to answer these questions), and post-visit person-in-context questionnaires and interviews, we will be able to get a good picture about what STEM exhibits engage visitors and why.

### 3.1.2 Media programmes

The tools will be based on digital learning analytics, i.e., user data regarding the attractiveness of different elements in the respective digital environment (e.g., the average percentage of users who used a given webpage and the average duration of user stay at this webpage.)

## *3.2 Tools for the person-in-context perspective*

The Person-in-Context Research Perspective is designed to provide insights regarding the interaction and experiences of the learners, from their perspective, based on *short questionnaires* related to their experiences, their appreciation and accessibility of the activity, perceived learning, and motivation to participate in similar and other science activities. The tools designed for this research perspective are short questions, to be answered by the learners after their activity.

### 3.2.1 Short questions for the 6 strands

There will be two short questions presented for each of the strands, one using a closed Likert scale and one using an open-ended format. The questions are presented in Table 3.1.

**Table 3.1**. *The person-in-context questionnaire items.*

| | |
|---|---|
| **Strand 1:**<br>Interest | "The activity was interesting" (Likert)<br>"What I found interesting was …" (open)<br>A question I would like to ask about the activity is …(open) |
| **Strand 2:**<br>Knowledge | "I learned something from this activity." (Likert)<br>"What I learned was …" (Open) |
| **Strand 3:**<br>Reasoning | "The activity helped me understand and explain something in science that I couldn't explain before the activity." (Likert)<br>"I could explain that …" (Open) |
| **Strand 4:**<br>Reflection | "The activity helped me understand how scientists work." (Likert)<br>"I understood that scientists work by …" (Open) |
| **Strand 5:**<br>Tools/Language | "In the activity, I used the language and tools of science." (Likert)<br>"I used the following language and tools…" (Open) |
| **Strand 6:**<br>Science Identity | "In the activity, I saw myself as a science person." (Likert)<br>"Specifically …" (Open) |

These questions will be presented in the Science Chaser in two formats, one for primary school children, and the other for secondary school students. In the former format, the Likert questions will use faces  while in the latter format, these same questions will use numbers only (1=YES! 2 = Yes, 3 = Maybe, 4 = No, 5 =NO!). In the former format, the open-ended questions will be asked in an interview, while in the latter version, these questions can be answered in writing.

### 3.2.2 Optional questions for experienced emotions

In addition, the Semantic Differential Emotion Questionnaire, SDEQ (Yonai & Blonder, 2022; see Table 3.2) will be used for assessing outreach programmes; for the other learning contexts, this tool will be optional. The tool relates to the emotions experienced by the learners, during their experience in the outreach programmes. It is related to strand 1 (Interest and excitement in science).

**Table 3.2**. *The Semantic Differential Emotion Questionnaire (Yonai & Blonder, 2022).*

| **Positive feeling** | **Scale** | **Negative feeling** |
|---|---|---|
| **Interest** | **1 2 3 4 5** | **Boredom** |
| **Admiration** | **1 2 3 4 5** | **Disgust*** |
| **Enjoyment** | **1 2 3 4 5** | **Suffering*** |
| **Relief** | **1 2 3 4 5** | **Anxiety** |

| | | |
|---|---|---|
| **Relaxation** | **1 2 3 4 5** | **Anger** |
| **Pride** | **1 2 3 4 5** | **Shame** |
| **Hopeful** | **1 2 3 4 5** | **Hopeless** |
| **Excitement** | **1 2 3 4 5** | **Indifference** |
| **Love** | **1 2 3 4 5** | **Hate** |
| **Innovative** | **1 2 3 4 5** | **Obsolete** |
| **Cool** | **1 2 3 4 5** | **Not cool** |

## *3.3 Tools for the person-oriented perspective*

As mentioned above, this perspective provides insights about the outcomes that iSTEM learning activities have regarding the six strands of science proficiency, based on questionnaires and interviews given before and after the iSTEM activity. Because this perspective is based on a pre-post research design, it will provide rigorous evidence that can be used to establish causality, i.e., that a given activity or pathway is responsible for leading to a given outcome for a given target audience.

### 3.3.1 Strand 1: Being interested in and excited by science

The tool for Strand 1 is based on Linnenbrink-Garcia et al. (2010). A Likert scale will be used for the questionnaire items. In Table 3.3, we present the questionnaire items according the four stages of interest (Hidi & Renninger, 2006). The fourth stage – well-developed individual interest -- is not represented in this questionnaire, since we identify it as closer to science identity (Strand 6).

**Table 3.3**. *Questionnaire items for assessing Strand 1. Note that for each iSTEM activity, the wording of these items will be adapted to the appropriate activity and its area of science (e.g., biology/chemistry/physics/astronomy).*

| **Category** | **Number of items** | **Items** | **Alpha Cronbach** |
|---|---|---|---|
| Linnenbrink-Garcia, et al. (2010) | | | |
| 1.Triggered-situational interest | 4 | 1. I don't like (museum visits/outdoor visits/astronomy visits) very much<br>2. The (museum visits/outdoor visits/astronomy visits) aren't very interesting.<br>3. I enjoy coming to (museum visits/outdoor visits/astronomy visits).<br>4. Usually (museum visits/outdoor visits/astronomy visits) seem to drag forever | 0.781 |

| | | | |
|---|---|---|---|
| 2. Maintained situational interest | 5 | 5. I think the field of (biology/chemistry/physics/astronomy) is very boring<br>6. I think what we are learning in (biology/chemistry/physics/astronomy) is important<br>7. I see how I can apply (biology/chemistry/physics/astronomy) to everyday life<br>8. What we are learning in chemistry this year is not important for my future goals<br>9. I think this class is interesting this year | 0.731 |
| 3. Individual interest | 5 | 10. What we are learning in (biology/chemistry/physics/astronomy) this year is important for my future goals<br>11. (Biology/chemistry/physics/astronomy) helps me in my daily life outside of school<br>12. I don't like (biology/chemistry/physics/astronomy).<br>13. I'm don't enjoy (biology/chemistry/physics/astronomy)<br>14. Thinking about (biology/chemistry/physics/astronomy) is an important part of who I am | 0.785 |

### 3.3.2 Strand 2: Understanding science knowledge

Even with a more obtrusive assessment form, the goal is to make the tests as short as possible. Therefore, it is suggested to assess Strand 2 (Understanding Scientific Knowledge) and Strand 3 (Scientific Reasoning) together, with an interconnected set of questions.

The exact content and formulation of questions should be based on the materials and goals of a specific activity. Moreover, if the activity is provided for students of different ages, different questions can be chosen for specific age groups. The template is presented below.

Part 1. One or two blocks of questions about the same subject, where

- Question 1 – checks factual knowledge (open-ended or a MC question)
- Question 2 – checks conceptual knowledge (open-ended or a MC question)
- Question 3 – checks conceptual knowledge with focus on scientific reasoning

Part 2. A task on visual representation of the topic, such as concept maps, diagrams, drawings to check conceptual and procedural knowledge.

Part 3. One or two questions checking reasoning behind a given solution or applying knowledge to a real-life situation (knowledge transfer).

A summary of the assessment approach is shown in Table 3.4.

**Table 3.4**. *Assessment instruments and corresponding Science Proficiency (SP) strands*

| **Assessment instruments** | **Assessed SP strands** |
|---|---|
| Blocks of open-ended and MC questions (levels of understanding, applying, analysing and evaluating) | (several types of) knowledge and scientific reasoning connected to the same topic |
| Visual representation of integrated understanding (e.g., concept maps, diagrams) | (several types of) knowledge and scientific reasoning connected to the same topic |
| Tasks to explain a situation/process or to suggest a solution to a real-life problem | scientific reasoning |

Example of a test for secondary schoolchildren about dinosaurs:

Part 1 (one or more blocks can be used)

Block 1

Q1: What is a dinosaur? (or a MC question)

Q2: What is the connection of dinosaurs and animals living now?

Q3: Why do scientists study dinosaurs?

Block 2:

Q1: Name three types of dinosaurs (or a MC question)

Q2: How can we distinguish different types of dinosaurs?

Q3: Why did different types of dinosaurs exist?

Part 2

Create a concept map about dinosaurs, use the following words: extinct, predator, wings, eggs and other words you think are important. Show how concepts are connected and name the connections.

Part 3

- Q1: What can we learn from dinosaurs about evolution?
- Q2: What happens to the life on Earth if the dinosaurs will re-appear? Why?

Another example of a knowledge item for primary schoolchildren:

You want to find out which would empty from a can the fastest—water, alcohol, cooking oil, syrup, or soda pop. To answer this question, you will need equal amounts of the liquids as well as which of the following?

a) a can with a hole in the bottom and a stopwatch
b) a stopwatch only
c) cans with different sized holes
d) cans of different sizes, one for each liquid

A different approach to evaluate students' knowledge gains that can be suitable for iSTEM activities is by applying a prompt of a photograph that is related to the topic of the activity. The students are presented to the photograph (e.g., Figure 3.5) and are asked to pay attention to details and to write their thoughts about the topic of the activity.

**Figure 3.5.** *A food-related topic photo.*

The participants will be asked to pay attention to details and write their thoughts about the topic of the activity (food and nutrition) that emerged from the photos. A comparison between the pre and post responses of the students will expose the knowledge gained by students. This research tool is based on PhD dissertation of Tal Yachin, student of Prof. Miri Barak, Technion, Israel.

### 3.3.3 Strand 3: Engaging in scientific reasoning

Questions are connected or are a part of questions to assess understanding of science knowledge (Strand 2). As with Strand 2, a tailored set of open-ended questions, explanation questions and visualization tasks are available for the case studies. Some examples of open-ended questions, explanation questions using a "What if? format, and visualization tasks are given below.

Open-ended questions.

Why do scientists study dinosaurs?

Why did different types of dinosaurs exist?

What happens to the life on earth if the dinosaurs will re-appear?

Explanations.

What can you say about characteristics of an object if it floats in water but sinks in oil?

Can you draw what happens to a glass of a water and vinegar mixture after you add toothpaste?

Explain how and why diffusion is used in everyday life?

<u>Visualization tasks</u>.

Scientific reasoning can be assessed through visual representations of the topic, such as mind maps (Figure 3.6), concept maps (Figure 3.7) or argumentation maps (Figure 3.8). All these tools encourage students to visualize their conceptual understanding and to provide an appropriate rationale.

An example of a visualization task follows:

> Create a concept map about dinosaurs, use the following words: extinct, predator, wings, eggs and other words you think are important. Show how concepts are connected and name the connections.

**Figure 3.6**. *An example of a mind map (Falk, & Dierking, 1992)*


**Figure 3.7.** *An example of a concept map (Novak, & Cañas, 2006)*

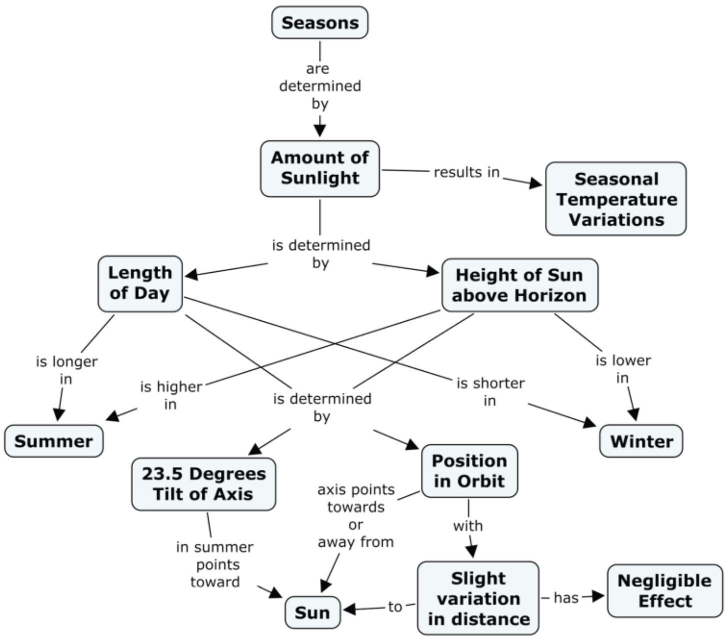
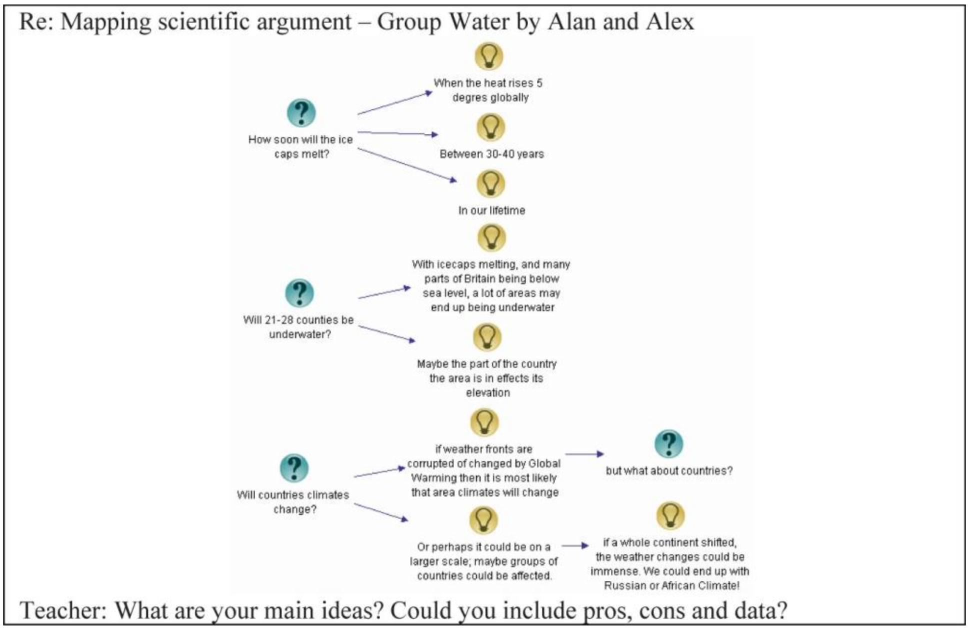


**Figure 3.8**. *An example of a concept map (Okada, 2008)*




It is important to note that case studies that will include strands 2 and 3 will adapt the items to the scientific topic each of the case studies. The adaptation process will be undertaken by the activity provider with a representative of WP5, in order to validate the different levels of knowledge and scientific reasoning and the accurate connection to the specific activity.

### 3.3.4 Strand 4: Reflecting on science

The tool that provides a quality test for the Nature of Science (NOS) is the questionnaire developed by Conley (2004) and verified with students of different age groups by Schiefer (2022). The questionnaire tests for 4 different related components of learners' concepts about the NOS: (a) source (To what extent is the source of scientific knowledge based on authority or evidence?), (b) certainty (To what extent is scientific knowledge certain or tentative?), (c) development (To what extent do scientific ideas change?), and d) justification (To what extent are experiments and data important for supporting scientific arguments?).

The tool presents statements for each of these components. For each statement, a Likert scale is presented, ranging from agree to disagree. Below are self-report items used to measure each of the components of epistemological beliefs.

<u>Source</u>

- Everybody has to believe what scientists say.
- In science, you have to believe what the science books say about stuff.
- Whatever the teacher says in science class is true.
- If you read something in a science book, you can be sure it's true.
- Only scientists know for sure what is true in science.

<u>Certainty</u>

- All questions in science have one right answer.
- The most important part of doing science is coming up with the right answer.
- Scientists pretty much know everything about science; there is not much more to know.

- Scientific knowledge is always true.
- Once scientists have a result from an experiment that is the only answer.
- Scientists always agree about what is true in science.

Development

- Some ideas in science today are different than what scientists used to think.
- The ideas in science books sometimes change.
- There are some questions that even scientists cannot answer.
- Ideas in science sometimes change.
- New discoveries can change what scientists think is true.
- Sometimes scientists change their minds about what is true in science.

Justification

- Ideas about science experiments come from being curious and thinking about how things work.
- In science, there can be more than one way for scientists to test their ideas.
- One important part of science is doing experiments to come up with new ideas about how things work.
- It is good to try experiments more than once to make sure of your findings.
- Good ideas in science can come from anybody, not just from scientists.
- A good way to know if something is true is to do an experiment.
- Good answers are based on evidence from many different experiments.
- Ideas in science can come from your own questions and experiments.
- It is good to have an idea before you start an experiment.

### 3.3.5 Strand 5: Using the tools and language of science

Depending of the goals and the nature of the activity, questions about operating equipment can be explicit or not. If the activity aims at teaching participants about specific piece of equipment or technology, questions can be asked about the ways or the reasons to use them. However, if the equipment is used to get data and interpret them, the usage of the equipment can be assessed implicitly by checking the mentioning of the right piece of technology when answering questions related to assessing strand 2 *understanding of scientific knowledge* and strand 3 *scientific reasoning*.

The use of the language of science is always assessed implicitly by analysing the answers to content-related questions. For this, “De-Jargonizer” (https://scienceandpublic.com/) – a tool for automatic analysis of scientific jargon level in the text – will be used with inputs from the answers to the open-ended questions of the knowledge tests.

Examples of the specific questions for assessing using of tools of science explicitly:

- What parts does a microscope include?
- What scientific principles is the work of microscope based on?
- What areas of science can we use microscope in? What for?

As mentioned earlier, perceived and experienced authenticity in science is also connected to the tools and language of science. Thus, we plan to measure this strand via the *perceived* *authenticity questionnaire.* This tool was developed by Boll (2013), tested and validated by Schwarzer and Parchmann (2015), and was also applied in Israel after it was translated into Hebrew (Yonai et al., 2022). The purpose of the questionnaire is to evaluate learners' experience of authenticity after a science laboratory activity. The questionnaire includes 7 items. One item (I communicated with scientists) refers directly to communicating with scientists. Five of the items present some possible experience of learning content (e.g., I learned about research devices; I learned about current important research questions). All of these items can be attributed to authentic context, authentic tasks, and access to expert performance. An additional item is added that refers to the connection of research to everyday life.

The perceived authenticity questionnaire (Boll, 2013) includes the following 7 items:

1. I communicated with scientists.
2. I learned how work is done in research.
3. I learned about current important research questions/topics.
4. I learned about employment options in scientific research.
5. I learned about research devices.
6. I learned to interpret and analyze scientific research.
7. In the course I experienced a real scientific environment.

In addition to the above seven validated questions, the Surrounded by Science project would like to add an additional item to this questionnaire that focuses on the connection of science to everyday life.

8. I learned about the connection of research to everyday life.

### 3.3.6 Strand 6: Identifying with the scientific enterprise (science identity)

There have been various tools developed to measure science identity consistent with a person-oriented approach. These constructs can be classified into two main perspectives: (1) type of person perspective (Table 3.4); and (2) internal and external recognition perspective (Table 3.5). These two perspectives can be combined into a 4-item questionnaire.

**Table 3.4.** *Type of person perspective.*

| **Author(s)** | **Item(s)** | **Likert scale** | **Cronbach's alpha** |
|---|---|---|---|
| Robinson et al. (2019) | 1. I consider myself a science person.<br>2. Being involved in science is a key part of who I am.<br>3. Being someone who is good at science is important to me.<br>4. Being good in science is an important part of who I am. | 1 (strongly disagree) to 5 (strongly agree) | .85-.87 |

**Table 3.5.** *Recognition perspective.*

| Author(s) | Item(s) | Likert scale | Cronbach's alpha |
|---|---|---|---|
| Roberts & Hughes (2022) | *Internal recognition*<br><br>- Science is something I rarely even think about.<br>(reverse coded)<br>- I would feel a loss if I<br>were forced to give up<br>doing science<br>- I really don't have any<br>clear feelings about science. (reverse coded)<br>- Science is an important part of who I am<br>- Being a scientist is an<br>important part of my identity<br>- No one would really be<br>surprised if I just stopped doing science. (reverse coded)<br><br>*External recognition*<br><br>- Many people think of me in terms of being a<br>scientist<br>- Other people think doing<br>science is important to me<br>- It is important to my friends and relatives that I continue as a scientist<br>- Many of the people that I know expect me to continue as a scientist | 1 (strongly disagree) to 5 (strongly agree) | 0.832<br><br>*0.904* |

**Table 3.6.** *Type of person and recognition perspective combined.*

| Author(s) | Item(s) | Likert scale | Cronbach's alpha |
|---|---|---|---|
| Vincent-Ruz & Schunn (2018) | 1. I am a science person<br>2. My family sees me as a science person<br>3. My friends see me as a science person<br>4. My teachers see me as a science person | 1 = NO!<br>2 = No<br>3 = Yes<br>4 = YES! | 0.84 |

Adapted from Aschbacher et al. (2010) and Shanahan (2009), the science identity 4-item scale designed by Vincent-Ruz and Schunn (2018) aims at testing whether and which internal components of science identity cohere with external components. As such, by employing a 4-point Likert-type scale (ranging from 1=No! to 4=Yes!) the construct focuses on measuring:

- *Perceived personal science identity*, where respondents are asked to indicate the degree to which they view of themselves as being the kind of person associated with science.

- *Perceived recognised science identity*, where respondents are asked to indicate the degree to which they perceive that influential others (friends, family, and teachers) see them in this way (with one item per each of the three influential others).

The proposed science identity scale is chosen as it presents several advantages compared with other measures found in the literature:

- It overcomes the dualist opposition between internal and external components of science identity.
- It overcomes the conflation of science identity with the related but distinct science attitudinal measures such as self-efficacy, competency beliefs and interest in science that have been conceptualised as components of science identity.
- It overcomes the "length issue" as it includes only 4 items compared to the 10-item questionnaire of internal and external science recognition by Roberts & Hughes (2022).

The science identity questionnaire (Vincent-Ruz & Schunn, 2018) includes the following four items:

i. I am a science person
ii. My family sees me as a science person
iii. My friends see me as a science person
iv. My teachers see me as a science person

The science identity 4-item scale exhibits good psychometric properties: factor structure, reliability, and concurrent validity. In addition, differential item functioning analyses indicated no differential functioning by gender, race/ethnicity, or age at any of the science identity items.

Another concept that underlies strand 6 is self-perception in science. This concept has been used by PISA using the items in Table 3.7. The value of gathering data using these items is that we can calibrate the findings with similar PISA data taken around the world (OECD, 2016). This concept is also called self-concept in science (Malte & Ludtke, 2014).

**Table 3.7.** *Items used to assess self-perception in science (OECD, 2016).*

| Category | Number of items | Items | Alpha Cronbach |
|---|---|---|---|
| Self-perception in science | 7 | 1. I can usually give good answers to test questions on (biology/chemistry/physics/astronomy) topics<br>2. I learn (biology/chemistry/physics/astronomy) topics quickly<br>3. (biology/chemistry/physics/astronomy) topics are easy for me<br>4. I can easily understand new ideas in (biology/chemistry/physics/astronomy)<br>5. Learning advanced | 0.891 |

| | | | |
|---|---|---|---|
| | | (biology/chemistry/physics/astronomy) topics would be easy for me<br>6. When I am being taught (biology/chemistry/physics/astronomy), I can understand the concepts very well<br>7. It would be easy for me to recognize scientific questions in an article about (biology/chemistry/physics/astronomy) | |

### 3.3.7 Measuring other concepts in the person-oriented perspective

In addition to measuring the 6 strands of Science Proficiency, we could assess other outcome concepts, such as self-efficacy, motivation, and trust in science. A review of these concepts shows that they are very close to the concepts underlying the 6 strands. Strand 1 (Being interested in and excited by science) relates to the concept of motivation. Strand 4 (Reflecting on science) includes trust in science. Strand 6 (Identifying with the scientific enterprise, or science identity) includes the concept of self-efficacy.

Tools are available to assess these concepts. Motivation can be assessed with instruments such as the Science Motivation Questionnaire II (Glynn et al., 2011) and the Intrinsic Motivation Questionnaire (IMI, n.d.). Trust in science can be assessed with instruments such as the Credibility of Science Scale (Hartman et al., 2017). Self-efficacy can be measured only indirectly (Judge, 2009), often in the form of self-report surveys (Cassidy & Eachus, 2002); it could be argued that the perceived competence scale of the Intrinsic Motivation Inventory (IMI, n.d.) measures an aspect of self-efficacy.

Due to the fact that the above concepts come so close to what we have chosen to measure in the 6 strands, we decided not to measure other concepts this coming year. After this round of research, in the summer of 2023, we plan to revisit this question of assessing other concepts, and may decide to do so in the 2023-4 school year.

## 3.4 *The everyday-life perspective*

This research perspective does not have its own unique research tools, as do the first three research perspectives. What is different about this perspective is that it incorporates learning ecologies and learning pathways. The tools presented in the first three perspectives will also be used to assess the fourth perspective.

In Section 2.2 of this deliverable, the everyday-life perspective was presented in principle. Below, this pathway is presented along with the example of learning activities designed by the project partner Ellinogermaniki Agogi (EA) for students in the first cycle of the project (2022-23).

### 3.4.1 Description of the everyday-life perspective by means of an example

In this section, we discuss how the everyday-life perspective will be implemented, given a particular example.

A learning pathway connects a person's learning across the many contexts, for example, home, school, community organisations, science centres and museums, games, web and social media where learning may occur. As an example, the learning pathway, "From Galileo discoveries to the detection of the gravitational waves" presents a learning pathway that crosscuts different learning environments. This pathway interconnects different educational settings, formal and informal: school, science museum, astronomy observatory, research infrastructure and web-based science related contents. It offers a concise introduction to ground-breaking scientific advances in modern astronomy from Galileo's first discoveries using his telescope back in the 1600s, to the recent direct observations of gravitational waves by the VIRGO detector.

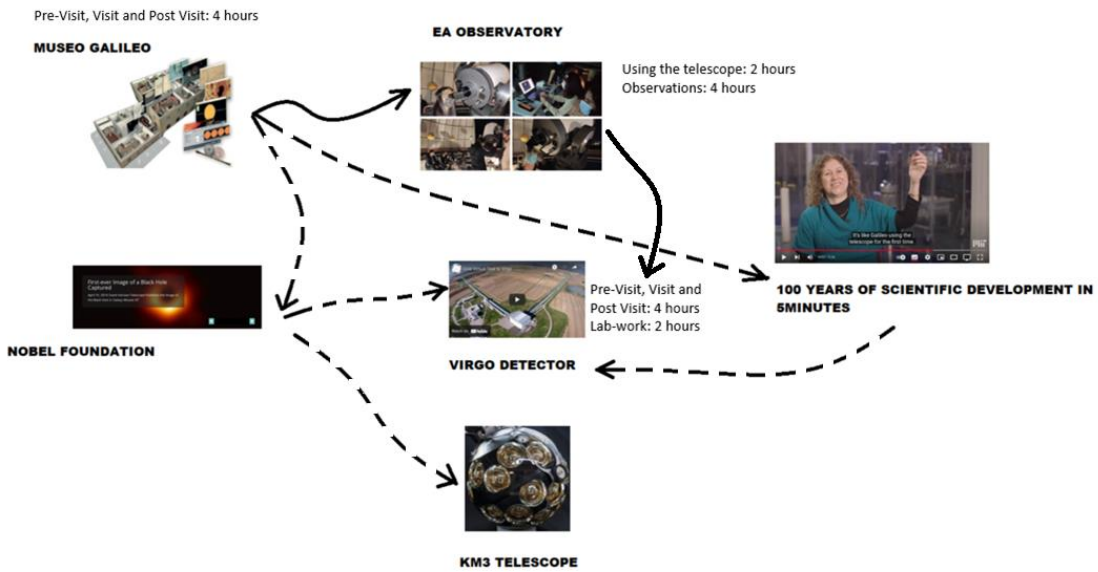



**Figure 3.4.1.** *A graphical representation of the proposed educational pathway that highlights the core activities (Museo Galileo, EA Observatory, VIRGO Detector), interconnected and enriched with additional content (interconnected with dashed lines) that will become available through the Science Chaser to each individual user to explore.*

Figure 3.4.1 graphically represents how this learning pathway is organized. For the core activities, an indicative time frame is proposed. This includes a museum visit, the operation of a telescope and the realization of a series of observations, lab-based experimentation and a virtual visit to the VIRGO gravitational wave detector. Additional activities and tasks will become available to the learners before or after the core activities. Learners will have the chance to follow their own paths in exploring the additional contents and resources. Based on their engagement the project team will have the chance to populate their Science Proficiency profiles and to provide evidence for the integrated impact assessment of the proposed pathway.

The assessment of a learning pathway is based, to a great extent, on the tools presented earlier in this deliverable. In the example, the proposed pathway will be assessed by an appropriate set of the tools that were proposed in the previous chapters, along with a series of interventions that will be embedded in the learning experiences using the Science Chaser application. For example, the Science Chaser could trigger online discussions that facilitate science learning by enriching learners' experience. This could be done by exploring in depth the themes under study, by focusing on the sophistication of the scientific terminology used in online discussions explored and how participation in the guided online intervention is correlated with scientific reasoning and understanding of the phenomena in question as measured by, for instance, a set of custom designed image-based science quizzes. By integrating the outcomes of the tools proposed in the previous chapters, which could be applied as pre- and post-study interventions, and the logfiles from monitoring learners' interactions with the Science Chaser (e.g., monitoring the alternative paths the learner has followed in between the core pathway activities), the project team aims to identify potential correlations between the involvement in the online interactions guided by the Science Chaser and the documented learning outcomes.

Details of the combination of the evaluation tools with the use of the Science Chaser application and data acquisition in the course of the pathway are presented in the next section.

### 3.4.2 Assessment of the strands of Science Proficiency

The main aim of the everyday-life research perspective is to study how out-of-school activities (virtual and physical visits to museums, science centres, and research infrastructures) can be used to provide engaging educational experiences through the exploration of "real science" that could lead to significant learning outcomes. During the implementation of the proposed activities, learners will be engaged in "border crossings" from their own everyday world culture into the subculture of science. The subculture of science (i.e., a collective set of norms, practices, language, and tools) is in part distinct from other cultural activities and in part a reflection of the cultural backgrounds of scientists themselves. By developing and supporting experiences that engage learners in a broad range of science practices, we can increase the ways in which learners identify with and make meaning from their science learning experiences.

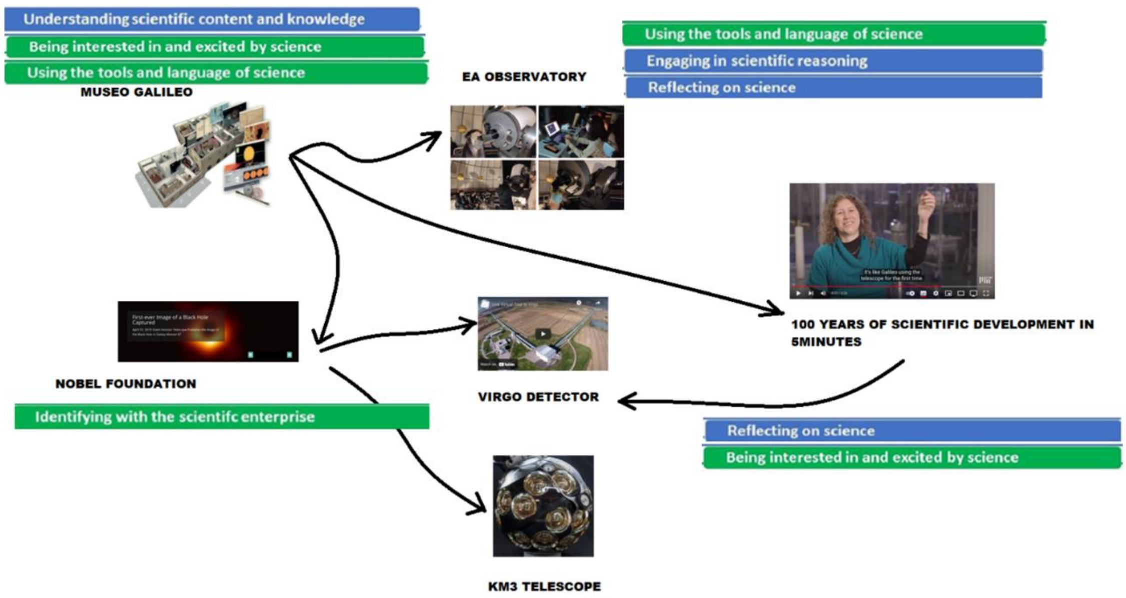



**Figure 3.4.2.** *According to the educational design of the educational pathway each individual activity contributes at a different level to the six strands of Science Proficiency. The development of competence in the different strands could be further enhanced by enriching the learner experience with additional activities bridging the core ones.*

For example, in the learning pathway “From Galileo discoveries to the detection of the gravitational waves”, the project team has predicted what would be the expected impact of the core activities on the outcomes of the strands of Science Proficiency. The design of the learning pathway aims to affect the learning outcomes of all six strands, albeit to varying degrees per strand, depending on the goals and nature of each activity (see Figure 3.4.2). These expectations -- about how the learning outcomes will be influenced by the learning pathway -- are reflected by the educational objectives that guide the design of each activity in a learning pathway. In each learning pathway, there are broad educational objectives of the pathway as a whole, and more specific learning outcomes for each specific activities of the pathway.

The broad educational objectives of the example as a whole are presented in Table 3.4.1., while more specific learning outcomes of each core activity of the learning path are described in Table 3.4.2. The evaluation aims to reveal the extent to which, and how, learners’ lived learning experience during the field research will represent this expected impact on the six strands of Science Proficiency.

**Table 3.4.1.** *The broad educational objectives of the “From Galileo discoveries to the detection of gravitational waves” (based on the strands of Science Proficiency).*

| **Science Proficiency Strand** | **Educational Objectives** |
|---|---|
| Reflecting on Science | By the end of this learning path, learners will be able to:<br>• Reflect on the Nature of Science;<br>• Reflect on the core process of the Universe (from motion of heavenly bodies to disturbances of spacetime itself)<br>• Reflect on the evolution of Astronomy over time;<br>• Reflect on the evolution of the modus operandi of science in a procedural context (from one researcher with a simple telescope to large international collaborations operating large research infrastructures), |

| | |
|---|---|
| | • Reflect on the potential impact of the sociocultural context (from Galileo's conflict with the Aristotelian status quo to today's difficulty in explaining the progress of science to the untrained citizen) context;<br>• Reflect on the impact of technological development on the progress of science as well as the impact of science on the development of technology; |
| Using the tools and language of science | By the end of this learning path, learners will:<br>• get familiarized with tools and practices of science.<br>• get familiarized with the characteristics and the impact of the two major scientific revolutions<br>• get familiarized with scientific and evidence-based argumentation |
| Identifying with the scientific enterprise | By the end of this learning path, students will be able to:<br>• develop the identity as science learners and science contributors.<br>• contrast themselves with the early Astronomers like Galileo as well as modern scientists and develop the identity of a science learner.<br>• go beyond school science and learn how to contribute to science through their involvement in real scientific work |

**Table 3.4.2.** *Pathway core activities educational objectives (based on the strands and constructs of Science Proficiency).*

| Core Activity | Science Proficiency Strand | Educational Objectives |
|---|---|---|
| **MUSEO GALILEO**<br>Students will learn about Galileo's life and astronomical observations. They will reflect on what science is and how it is done and they will realize that science interacts with society. Students will study the way our perception of the Earth's place inside the Cosmos changed and Galileo's contribution to that. They will have the opportunity to see some of the instruments he used and are still preserved in Galileo Museo in Florence and discuss about his work on other fields as well.<br><br>**EA OBSERVATORY**<br>In this outreach program, participants acquire hands on experience in the operation of modern telescopes and conduct observations of planets such as Venus and Saturn by using a modern telescope. They gather evidence of their observations by taking photos of the astronomical objects in question using dedicated equipment, analyzing and synthesizing them to produce a final output and comparing them with observations of Galileo as well as images taken by satellites. | **Understanding scientific content and knowledge** | Students will be able to understand and use concepts and explanations (based on scientific facts) about the planetary system, the motion of the Earth and the tools we use to measure these. |
| | **Engaging in scientific reasoning** | Students will be able to Predict, Observe and Analyze phenomena related to the solar system through hands on work and testing. |
| | **Reflecting on science** | Students will be able to reflect on science as a way of learning by revisiting the Galilean and the Aristotelian view of the Cosmos. |
| | **Being interested and excited by science** | Students will be able to experience fascination by exploring related phenomena and resources as well as by being able to replicate and expand upon historical observations themselves using modern tools. |
| | **Using the tools and language of science** | Students will be able to use tools and language of science to demonstrate how the world works and enhance their trust in Science |
| | **Identifying with the scientific enterprise** | Students will be able to identify with science as a way of living by following the steps of Galileo: they will be able to immerse themselves in models to explain the world and apply Galileo's paradigm and tools used to everyday life (e.g., using proportional reasoning) |

| Core Activity | Science Proficiency Strand | Educational Objectives |
|---|---|---|
| **VIRGO DETECTOR**<br>In this stage, students are introduced to aspects of General Relativity and explore one of its major consequences: Gravitational Waves. Similarly, to how Galileo turned the telescope to the sky and opened a new observational window to the Universe, students learn how modern scientists use gigantic laser interferometers such as Virgo to observe the aftermath of cataclysmic cosmic phenomena. They perform hands -on activities in order to understand how the interferometer works, they do a virtual visit to the Virgo Gravitational Wave Detector in Pisa and finally they learn how they can contribute to cutting edge research in Gravitational Wave Astronomy through Citizen Science projects and related activities. | **Understanding scientific content and knowledge** | Students will be able to understand and use models and facts (based on scientific data) about the structure of the Universe and the major processes that govern the Cosmos (Gravity, Space-time). Students will be able to identify how concepts already familiar to them have been altered in our modern understanding of nature (From the absolute Space and Time to the “stretchy” Spacetime, from instantaneous gravitational interaction to spacetime curvature) |
| | **Engaging in scientific reasoning** | Students will be able to operate a simple experimental apparatus (Michelson interferometer), to manipulate it in order to produce a specific effect (interference), to test it (identifying how sensitive it is to small displacements) and to explore how this model scales up and becomes more sensitive to measure tiny distortions of space (Gravitational Waves). |
| | **Reflecting on science** | Students will be able to reflect on the Theory of Relativity (lightly). They will be able to argue about how we can measure something that Einstein himself declared impossible to measure 100 years before and they will be able to reflect on how science has progressed to work with objects and procedures far beyond the common sense (visualizing/sonifying the invisible). Students will be able to reflect on how our perception of the cosmos has changed (from a pristine sky before Galileo, to the violent Universe today). Finally, students will be able to reflect on how science is done in the modern days. |
| | **Being interested and excited by science** | Students will be able to develop their interest in science and experience excitement by exploring the complementary research efforts to study the Cosmos (Multimessenger Astronomy, High Energy Physics). |
| | **Using the tools and language of science** | Students will be able to develop trust in science by using tools of science to visualize the invisible and approach how the cosmos was created. |
| | **Identifying with the scientific enterprise** | Students will be able to identify themselves as science learners (science as a way of living) by comprehending the scientific process (from theoretical model to experiment, the use of technology, the proof or rejection of the model and re-iteration). |

This approach means that a learning pathway’s educational objectives will guide the design of the activities in the pathway. In the above example, one set of educational objectives relates to the Nature of Science and to the key principles of scientific methodology (strand 4). In this example, the learning pathway scans a period of scientific development that lasted more than four hundred years will demonstrate the similarities (and the differences) of two scientific revolutions.

To better understand the Nature of Science outcome, it is necessary to succinctly describe Kuhn's (1962) views on the development of scientific knowledge and its benefits for the creativity domain. Following an investigation of the Copernican revolution in astronomy, and inspired by the contributions of Jean Piaget about the stages of cognitive development in children, Kuhn proposed that activity in a scientific field operates according to a cyclic pattern, which can be traced by studying the history of this field.

A scientific field of research generally forms what Kuhn called a paradigm, which is a set of guiding theories, concepts, notions, and methods that are more or less consensual within the scientific community interested in this field. Research in a given scientific field tends to follow a given paradigm and exploit it to produce knowledge in the field.

In other words, the members of this research field work within the borders of a current paradigm. This period is defined as ‘normal science’. In this period, findings that differ from expectations from the paradigm regularly appear. When they are relatively rare, these anomalies tend to be neglected.

However, when the anomalies accumulate and become irreconcilable with the existing paradigm, the research field experiences a crisis: a revolution occurs and a new paradigm that can address these anomalies is inaugurated. After this “paradigm shift”, a new cycle begins, with a new period of normal science within this new paradigm, which will encounter, at some point, new anomalies, experience a new crisis, and so on. For example, Newtonian mechanics, which was a scientific revolution when it was proposed in the 17th century, was a paradigm for normal science in physics for a long time. Then came Einstein, his successors, and a new scientific revolution based on a new conception of space and time.

Figure 3.4.3 offers an indicative graphical representation of the expected impact of the implementation of the proposed pathway on the different strands of Science Proficiency in “From Galileo discoveries to the detection of the gravitational waves”. The uses of specific tools to assess specific strands will allow the project team to assess the contribution of the different core activities, in regard to the development of Science Proficiency for the individual learners. Additionally, the implementation of the pathway will allow us to assess the impact of each of the core activities in the learning pathway.

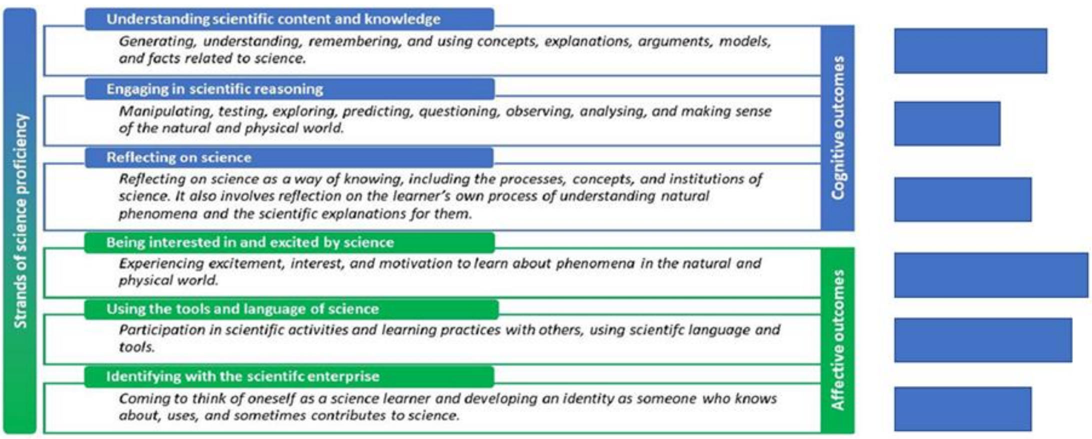



**Figure 3.4.3:** *Following the implementation of the pathway one can assess the impact of the integrated experience for the users involved.*

### 3.4.3 Collecting additional data through the Science Chaser

In each learning pathway, the use of the Science Chaser application will offer a unique opportunity not only to monitor learners' engagement with the proposed activities, but also to enhance this engagement. The Science Chaser can be used to trigger individual learners' interest and motivation to further explore the thematic areas, the concepts and the phenomena that are presented during the core activities. At the same time, it offers a rich collection of data that can provide evidence for the research findings based on the instruments that will be deployed to assess the impact on the Science Proficiency strands.

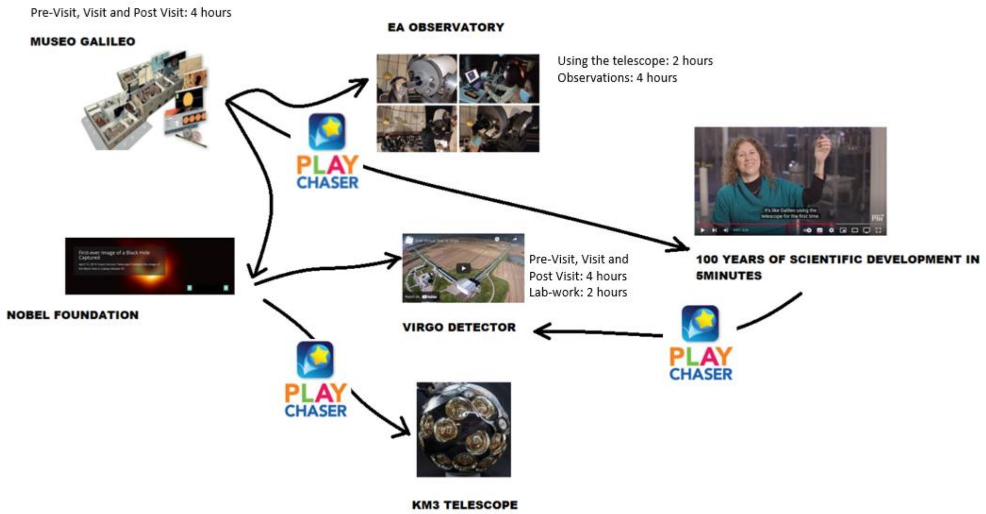



**Figure 3.4.4:** *The Science Chaser can be used at different points of the learning path to enhance the learner's experience and to assess the related engagement levels of each individual. It can introduce the learner to new educational paths that offer the opportunity to assess learner understanding of the concepts or the phenomena under study.*

For example, Figure 3.4.4 indicates some interaction points where the Science Chaser could be used to enhance the learner's experience, in the example described above. The use of the Science Chaser for the enrichment of the learning experience with additional digital content will contribute to offering learners a unified experience of journeys of scientific exploration in space and time, materializing transitions through digital archives, virtual exhibitions and simulations that represent the major moments in the history of science, as demonstrated in Figure 3.4.5.

**Figure 3.4.5.** *By using the Science Chaser the learner will be able to personalise the experience by e.g., repeating the experiments of Galileo through the integration of innovative tools that are available today (e.g., the learner will be able to study the phases of Venus using the Stellarium digital planetarium and compare them with the drawings of Galileo in 1610).*

Figure 3.4.6 offers a graphical representation of the content enrichment process that could be applied to each of the core activities of the proposed learning path. The learner can take advantage of numerous opportunities for the presentation of the development of scientific ideas during the time, connected with the historical and social context of their time. Starting from the core thematic sessions, learners can perform a time travel in the history of science till the origin of the scientific ideas and explore their development because of the continuous interaction between theory and experimentation, by using numerous digital resources and applications available on the web. For example, following the visit of Museo Galileo in Florence the learner will be able to continue exploring the discoveries and the archives of Galileo Galilei through different access modes. Through the Science Chaser the observations will be presented in a form of a storyline that will help the learner to realise the scientific process. Furthermore, the learner will be able to personalise the experience by e.g., repeating the experiments of Galileo through the integration of innovative tools that are available today (e.g., the learner will be able to study the phases of Venus through the use of the Stellarium digital planetarium (https://stellarium-web.org/) and compare them with the drawings of Galileo in 1610).

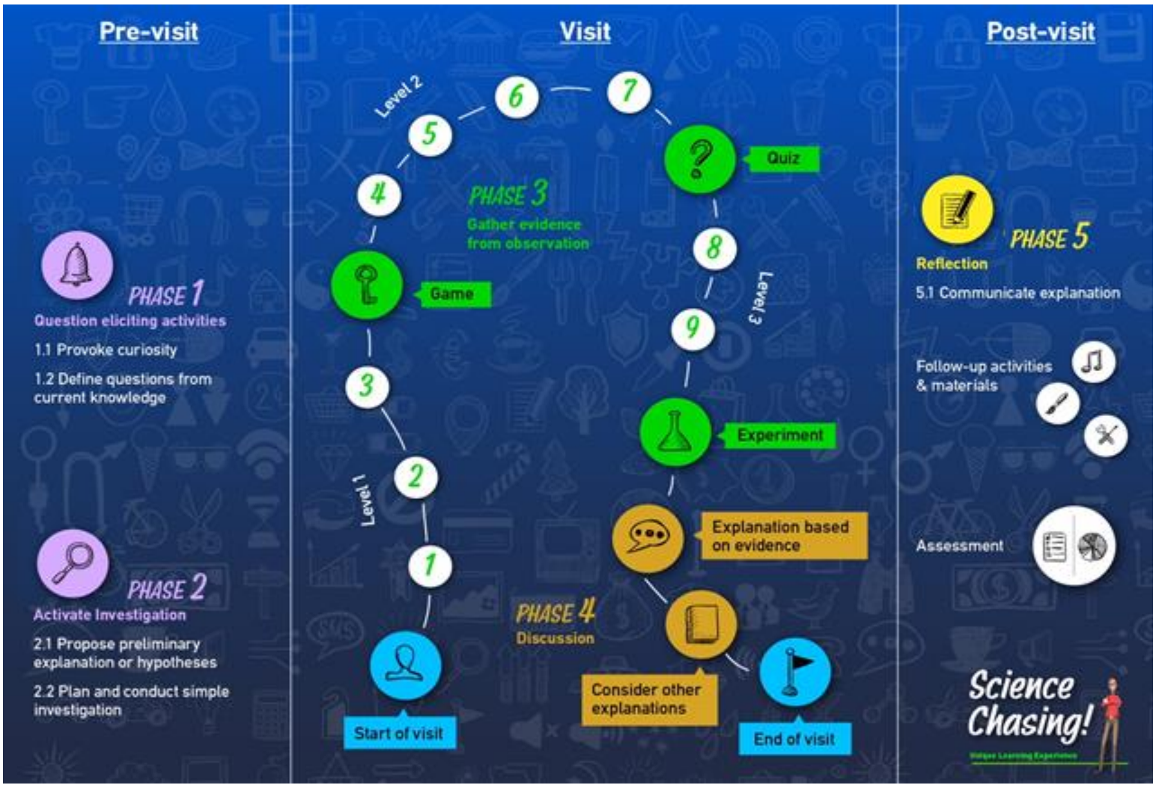



**Figure 3.4.6.** *An overview of possible interactions of the user with the Science Chaser app, a gamified instrument for assessing the six strands of Science Proficiency. Game assessment mechanics will map these strand competencies to assess both intellectual ability and fascination in a data-driven way. The figure presents (as an example) the interactions of a visitor of a science centre or a museum before the visit (e.g., through the museum website), during the visit (interaction with the exhibits) and after the visit (e.g., by exploring related science content on the web or visiting other museums).*

Figure 3.4.7 presents further potential features embedded in the Science Chaser which can be used by the learners during a core learning experience, forming part of the integrated pathway.

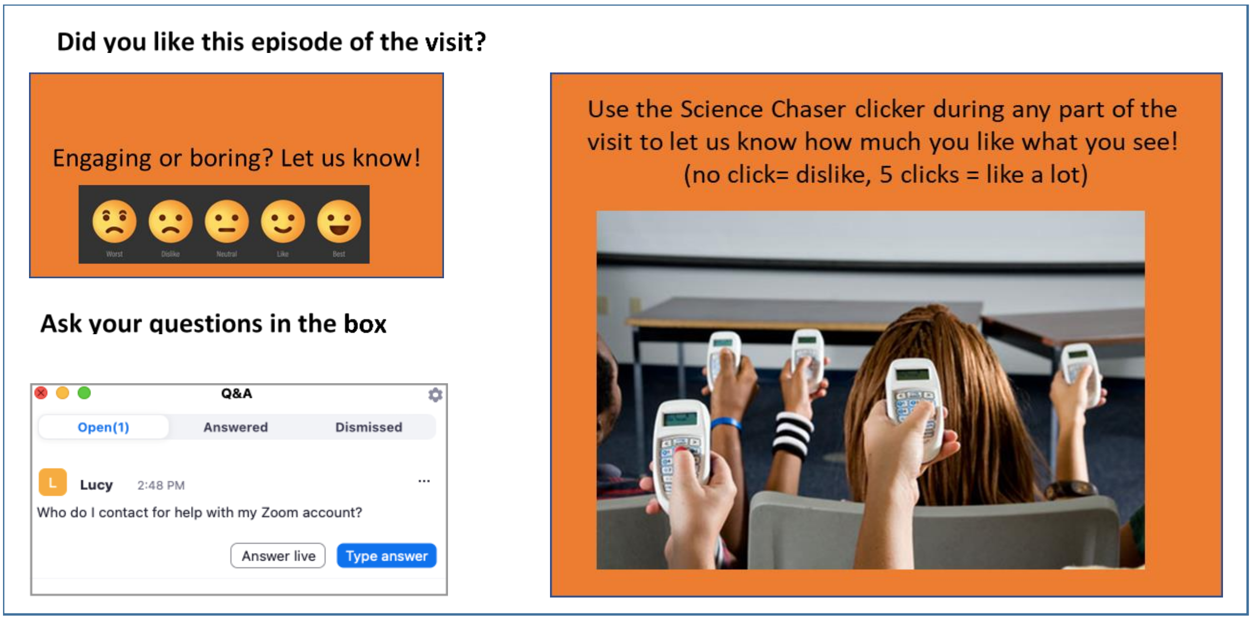



**Figure 3.4.7**. *Examples of features that could appear in the learner's view of the Science Chaser.*

Figure 3.4.8 presents a sequence of questions, tasks and image-based quizzes that could be implemented to enhance learners' fascination about the scientific discoveries of Galileo, as a follow up to the visit to the Museo Galileo in Florence.

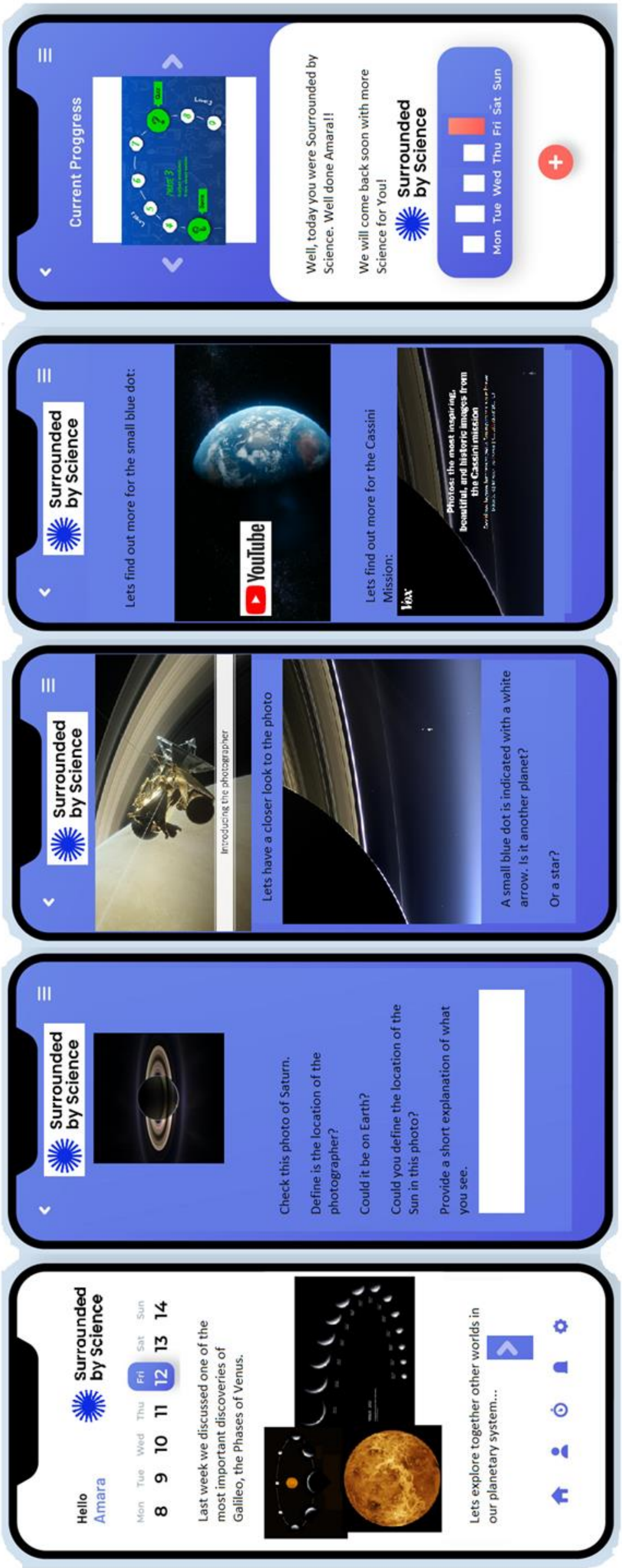


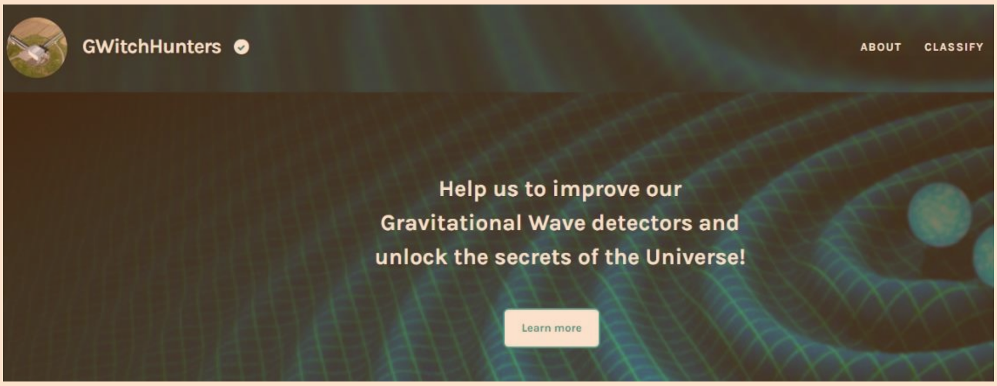

**Figure 3.4.8.** *A sequence of questions, tasks and image-based quizzes could enhance learners' fascination about the scientific discoveries that will be presented to the learners while they are visiting the Museo Galileo in Florence. While during the visit the discoveries of Galileo were presented, following the visit learners have the chance to reflect on the concepts and the phenomena that were presented. Through an inquiry-based process learners are introduced in new discussions and tasks that relate current discoveries and technological achievements with the initial ideas of the exploration of the sky and the universe. In this example the project team, following the presentation of the phases of Venus, the unique discovery of Galileo, is involving the learner to a series of tasks to assess her and his understanding of the planetary system, the positions of the Sun and the planets. Through the presentation of high-quality images of other worlds the learner has to apply pieces of the new knowledge to discover new unique phenomena related to our Solar System. The Science Chaser could also recognize the efforts of the learner.*

Furthermore, Figure 3.4.9 displays potential activities that could be offered after the virtual visit to the VIRGO Experiment through the Science Chaser, utilizing citizen science approaches that can enhance learners' engagement.

**Would you like to learn how you can contribute to cutting edge research in Gravitational Wave Astronomy yourself?**

The detection of Gravitational Waves is a challenging endeavor. Scientists have overcome a lot of obstacles, but they need your help. Background noise is affecting the sensitivity of Gravitational Waves detectors and therefore interfering with their ability to detect real astrophysical data. As you realize it is crucial to understand the origin of this noise and eliminate it.

**Become a Noise Hunter!**




You can join a project on Zooniverse called GWitchHunters to enable citizens to classify this noise in a user-friendly environment. You – as part of our research team and as a citizen scientist – will work with actual scientific data from the VIRGO Gravitational Waves detector and contribute to their improvement and the scientists' efforts to unravel the secrets of the Universe. Your classifications will serve as a basis to train machine learning algorithms that will automatically recognize and isolate noise in the Gravitational Waves data.

Learn more here: https://www.zooniverse.org/projects/reinforce/gwitchhunters

**Would you like to help spread the word about Gravitational Wave Astronomy to everyone?**

Check out these short videos prepared by other students and create your own! The most engaging videos will be shared in the Surrounded by Science Website and media!

**Figure 3.4.9**. *Example of message to learners in the Science Chaser proposing follow-up activities utilizing a Citizen Science approach.*

The use of the Science Chaser will be integrated in all steps of the pathway, not only to enrich the learning experience, but also to provide the research team as well as the activity providers with data and insights into the learning experience and learners' perception of it.

For example, user actions in the Science Chaser can automatically update user activity logs. A dashboard drawing input from the logs could be implemented to aggregate information that can be provided to the researchers and activity providers (Figure 3.4.10).

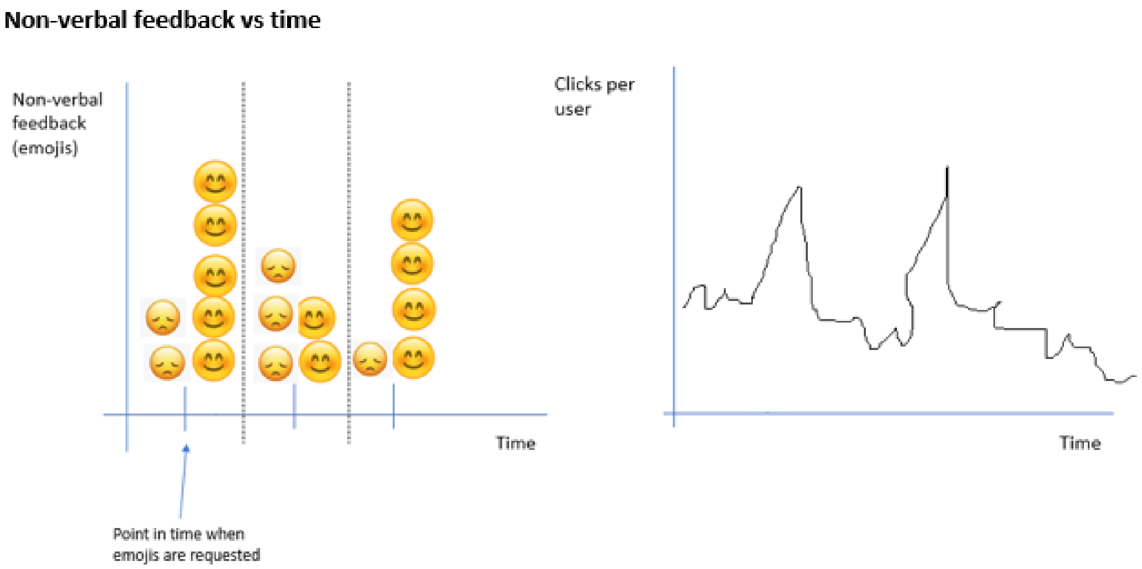



**Figure 3.4.10**. *Example Dashboard collecting information during learner's visit and presenting it to the researcher. Left: Non-verbal feedback provided by users at specific parts of a visit; Right: Clicks per user over time during the visit (The number of clicks can be used as evidence of represent user engagement).*

In addition, participants' activities can continue informing the relevant dashboard, in relation to how much time was spent in the Science Chaser, as well as the retention curves of the recorded visit. The dashboard could also offer summative utilities in which researchers track the performance of their activity by aggregating the relevant data from all visits they performed using the Science Chaser.

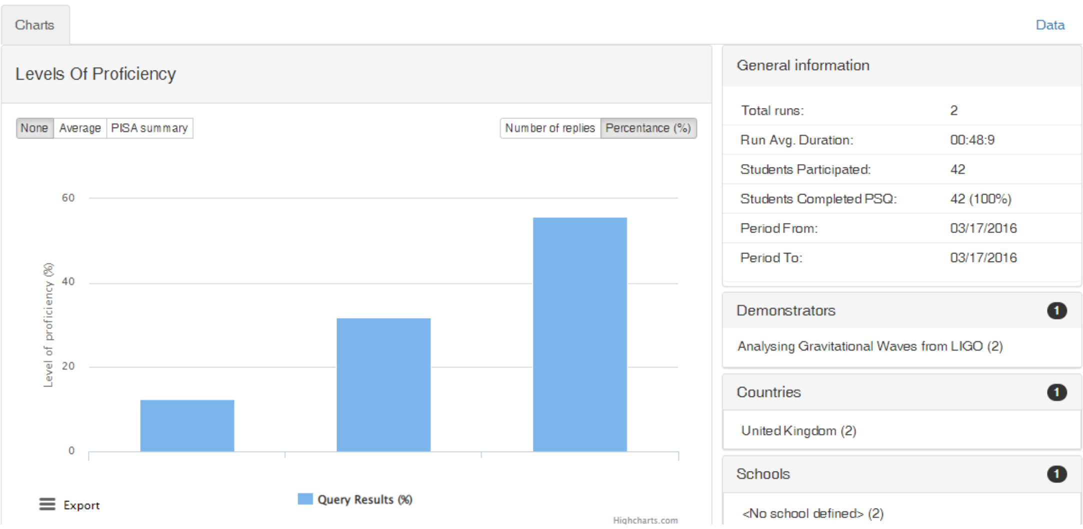



**Figure 3.4.11**. *Dashboard tool displaying the results per visit as well as the summative result for all visits based on the dedicated apps and actions that users perform.*


**Figure 3.4.12**. *Audience retention (fraction of users per time bin) revisiting the recording of the visit after broadcast*

Through the use of such activity logs and dashboard tools, one can collect feedback at the user level and the context level, in a summative fashion which in turn will support the optimization of the provided services.

### 3.4.4 Organization of the evaluation in the learning pathway study

This following section provides an overview of how the assessment of learning pathways can be organized. For example, in the “From Galileo discoveries to the detection of gravitational waves” learning pathway, an overview of the evaluation is visually summarized in Table 3.4.1.

**Table 3.4.1.** *Organization of the study of the integrated pathway in time and in connection to evaluation of the different strands of Science Proficiency for the From Galileo discoveries to the detection of gravitational waves" learning pathway.*

| **Time:** | **$T_0$ Baseline** | **$T_1$ pre-G** | **$T_2$ G** | **$T_3$ post-G** | **$T_4$ pre-O** | **$T_5$ O** | **$T_6$ post-O** | **$T_7$ pre-V** | **$T_8$ V** | **$T_9$ post-V** | **$T_{10}$ Conclusion** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| ***Bridging FL and IL*** | ***FL:*** | PreVS | | PostVS | PreVS | | PostVS | PreVS | | PostVS | |
| | ***IL:*** | FC | Visit FC | FC | FC | Visit/Club FC | FC | FC | Visit FC | FC | |
| | | | | | | | | | | | |
| ***Evaluation focus*** | **General pre-test** | | | Strand 2 Strand 3 | | | Strand 2 Strand 3 | | | Strand 2 Strand 3 | **General post-test** |
| | Strand 1 | 3.4.4.1.1.1.1.1 | | | | | | | | | Strand 1 |
| | Strand 4 | **Continuous data collection through the Science Chaser** | | | | | | | | | Strand 4 |
| | Strand 5 | | | | | | | | | | Strand 5 |
| | Strand 6 | | | | | | | | | | Strand 6 |

***Legend: G:*** *Galileo Museum Virtual Visit Programme;* ***O:*** *Observatory Science Club Programme;* ***V:*** *VIRGO Experiment Virtual Visit Programme;* ***FL:*** *Formal Learning contribution;* ***IL:*** *Informal Learning contribution;* ***PreVS:*** *Pre-Visit school activities;* ***PostVS:*** *Post-Visit school activities;* ***FC:*** *Free Choice / incidental learning experiences.* ***Strand 1:*** *Being Interested in and Excited by science;* ***Strand 2:*** *Understanding Scientific Content and Knowledge;* ***Strand 3:*** *Engaging in Scientific Reasoning;* ***Strand 4:*** *Reflecting on Science;* ***Strand 5:*** *Using the Tools and Language of Science;* ***Strand 6:*** *Identifying with the Scientific Enterprise*

The study is organized in 10 consecutive steps in time. While the duration of each step may vary, indicatively and on average it can be regarded as equivalent to a week. This renders an overall duration of 10 weeks (2.3 months) for the whole integrated pathway. Each of these steps in time coincides with a step of the design of the three central activities, plus one ‘baseline’ and one ‘conclusion’ time step before and after the whole pathway respectively. The sequence of activities includes the preparatory, core, and follow-up stages of three main activities (selected case studies): Galileo Museum Virtual Visit, Observatory Science Club, and VIRGO Experiment Virtual Visit. Reflecting a balanced synergy of formal and informal science learning the pathway includes pre- and post-visit school-oriented activities, as well as visits and free choice / incidental learning experiences in the realm of informal science learning.

During the study of the integrated pathway, data collection will be performed through a general pre- and post- test involving the administration of a questionnaire before the start and after the end of the whole pathway, as well as through continual data gathering using the Science Chaser. The purpose of the pre- post- design is to examine the emergence of any impact on aspects of participants’ Science Proficiency during the longer-term integrated learning experience. On the other hand, continual data collection through the Science Chaser aims at monitoring any effect on Science Proficiency strands during the evolution of the learning pathway over time. These two data collection modes are described in more detail below.

#### *3.4.4.2 General pre- and post-test*

In the general pre- and post-test, Strands 1, 4, 5, and 6 will be examined using the tools specified for the Person-Oriented perspective, appropriately selected and adapted, resulting in a tailor-made questionnaire.

For Strand 1 ‘Being Interested in and Excited by Science’, selected items from the relevant tool will be used. For Strand 4 ‘Reflecting on Science’, selected Items from the relevant questionnaire will be used to test the four components of learners’ concepts about the Nature of Science (source, certainty, development, and justification). For Strand 6 ‘Identifying with the Scientific Enterprise (Science Identity)’ selected items from the defined tool will be included to cover the two relevant perspectives (type of person, and internal and external recognition). Specific questions may also be included in the general pre- and post- test for Strand 5 ‘Using the Tools and Language of Science’, linked to the goals and the nature of the whole integrated pathway.

It is important to note that Strand 2 ‘Understanding Scientific Content and Knowledge’ and Strand 3 ‘Engaging in Scientific Reasoning’ are generally not included in the general pre- and post- test (apart maybe from only marginally), as those are predominantly bound to the context and content of the specific activities constituting the pathway. They will therefore be examined during the evolution of the integrated pathway using the Science Chaser, as described in the following section. Nevertheless, a small number of items related to Strands 2 and 3 and linked to the goals and nature of the whole integrated pathway, may be included in the questionnaire.

Finally, the pre- and post- questionnaire can be administered through the Science Chaser, as well as in other conventional ways (on paper, in a web form, etc).

#### *3.4.4.3 Continual data collection through the Science Chaser*

In all steps of the pathway, the Science Chaser will be used intensively, serving its dual purpose: a) to enhance learning by providing the participant with additional learning content and trigger events designed to extend the experience of attending the three central activities; and b) to gather additional data supporting the evaluation in connection to the six strands of Science

Proficiency. The continual data collection through the Science Chaser will serve the purposes of all three research perspectives.

**Person-oriented perspective**

From the person-oriented perspective, data collection through the Science Chaser will focus on Strands 2 and 3, implicitly contributing also to other strands, such as Strand 5. Specifically, Strand 2 'Understanding Scientific Content and Knowledge' and Strand 3 'Engaging in Scientific Reasoning' will be examined together in the specific context of each of the core activities of the pathway through an interconnected set of questions, the content and formulation of which will be based on the materials and goals of each activity. Appropriately tailored blocks of questions (open-ended, multiple-choice, what-if-and-why), as well as visual representation tasks (concept maps, diagrams) will be introduced to check factual and conceptual knowledge and scientific reasoning and will be introduced to check conceptual and procedural knowledge. In the Science Chaser, a variety of functionalities can be used to motivate and yield relevant participant input, from closed selection and open-ended text entry items to the creation of conceptual maps by the participants. In line with the methodology presented in this deliverable, the latter will allow to test conceptual knowledge at a deeper level, probing participants' understanding of relationships between concepts in a structured way. For Strand 5 'Using the Tools and Language of Science', the usage of equipment and the use of the language of science will be implicitly assessed through the answers to content-related questions linked to Strands 2 and 3, In addition, following each central activity participants will be exposed to appropriately selected and tailored items of the perceived authenticity questionnaire, to evaluate their experience of authenticity after the activity.

**Person-in-context perspective**

Continual data collection through the Science Chaser is also particularly relevant for the person-in-context perspective of the research. Through appropriately designed short interaction items materializing the relevant short questionnaires that have been defined, participants will provide input that will help gain valuable insights regarding their interaction and experiences with the various activities, from their own perspective. This will enable a continual monitoring of the evolving impact across the six Strands of Science Proficiency, as well as shedding light on participants' appreciation of the activities, their perceived learning, and their motivation to participate.

All above will take place both in moments of more intensive data collection after the end of activities (as post-activity studies), as well as less intensively during all preparatory, core, and follow-up steps of each activity, as appropriate depending on the nature of the activity.

Another person-in-context tool can be used as part of the assessment of the Everyday-Life Perspective: the Daily Activity in Science items (OECD, 2016). The items in this optional tool appear on a 5-point Likert-scale that can be administered, at various times throughout the student's engagement in the learning pathway. An advantage of using this tool is that the resulting data can be compared to international data taken for the same tool (OECD, 2016). See Table 3.4.2**.**

**Table 3.4.2** *Items in the Daily Activity in Science scale (OECD, 2016)*

| Category | Number of items | Items | Alpha Cronbach |
|---|---|---|---|
| Daily activity in science | 9 | 1. Watch TV programmes about science<br>2. Borrow or buy books on scientific topics<br>3. Visit web sites about scientific topics<br>4. Read science magazines or science articles in newspapers<br>5. I attend a science club<br>6. I perform simulationsof technical processes using computer software or by means of a virtual laboratory.<br>7. I visit the Internet websites of environmental organizations. I follow blogs or microblogs (e.g., on Twitter, status updates on Facebook) of organizations from the fields of science, the environment or ecology.<br>8. I visit the websites of environmental organizations.<br>9. I follow blogs or microblogs (e.g., on Twitter, status updates on Facebook) of organizations from the fields of science, the environment or ecology. | 0.882 |

### Context-oriented perspective

Finally, from the context-oriented perspective of the research, data gathered through the Science Chaser will offer valuable insights regarding characteristics of the activities that trigger attention and interaction in different contexts, i.e. with a special focus on Strand 1. This will be based predominantly on metrics and analytics provided to the researchers based on tracking participants' behaviour in the Science Chaser. Secondarily, from the same perspective researchers may be able to use other data collected through the Science Chaser to carry out additional analyses linked to the various strands of Science Proficiency. The observational and qualitative tools defined for the context-oriented perspective will inform the design of interactive items to be used by the participants as well as relevant metrics to be developed by the research team.

# 4. Conclusion

The Surrounded by Science project is based on the premise that "schools cannot act alone ... to improve science education broadly" (NRC, 2009). Based on the rationale of bridging between formal and informal STEM activities, this deliverable has presented a methodology and the tools to assess the impact of the iSTEM case studies on the 6 strands of Science Proficiency for different target audiences. What follows is a summary of this plan, how it is expected to address the project's research questions, and the project's next steps.

## *4.1 Summary of research perspectives, strands and tools*

Table 4.1 provides a summary of the first three research perspectives; included for each is a description, the learning contexts where they will be used and their target audiences. The context-oriented and person-in-context research perspective apply to all three learning contexts; the person-oriented perspective applies to all three learning concepts except for the designed environments for adults and family groups.

**Table 4.1.** *Summary of the first three research perspectives*

| | **Context-Oriented Perspective** | **Person-in-Context Oriented Perspective** | **Person-Oriented Perspective** |
|---|---|---|---|
| **Description** | Characteristics that trigger attention and interaction via *observation* | Personal interactions and experiences of the learners via *self-report tools* | Outcomes for the strands via *pre-post tools* |
| **Learning contexts** | All 3 contexts: Outreach programmes, designed environments, and technology and media products | All three contexts | All three contexts except for the designed environments for adults and family groups |
| **Target audiences** | School groups<br>Family groups<br>Adults | School groups<br>Family groups<br>Adults | School groups |

Table 4.2 summarizes the tools to be used in each of these three research perspectives, as they relate to the 6 strands of Science Proficiency. The everyday-life research perspective (the fourth perspective) will use the tools presented in Table 4.2, as described in Section 3.4.4.

**Table 4.2** *Summary of tools to be used in each perspective, across the 6 strands.*

| | **Context-Oriented Perspective** | **Person-in-Context Oriented Perspective** | **Person-Oriented Perspective** |
|---|---|---|---|
| **Strand 1. Being interested in and excited by science** | Visitor tracking, timing and observation sheet (designed environments)<br><br>Visit conversations form (designed | "The activity was interesting" (Likert)<br>"What I found interesting was…"(open-ended)<br>"A question I would like to ask is…"(open-ended) | Interest Questionnaire (Linnenbrink-Garcia et al., 2010) |

| | | | |
|---|---|---|---|
| | exhibits)<br><br>Data analytics (technology and media products) | Semantic Differential Emotion Questionnaire<br>(Yonai & Blonder, 2022)<br>(outreach programmes) | |
| **Strand 2: Understanding scientific content and knowledge** | | "I learned something from this activity." (Likert)<br>"What I learned was…" (Open-ended) | Tailor-made questions to test for factual, conceptual and/or procedural knowledge.<br>Visual representation, e.g., concept maps |
| **Strand 3: Engaging in scientific reasoning** | | "The activity helped me understand and explain something in science that I couldn't explain before the activity." (Likert)<br>"I could explain that …" (Open) | Tailor-made questions to test for participants being able to make sense of natural phenomena<br>Visual representation, e.g., concept maps |
| **Strand 4: Reflecting on science** | | "The activity helped me understand how scientists work." (Likert)<br>"I understood that scientists work by …" (Open) | Nature of Science Questionnaire (Conley, et al., 2004)<br>Visual representation, e.g., concept maps |
| **Strand 5: Using the tools and language of science** | | "In the activity, I used the language and tools of science." (Likert)<br>"I used the following language and tools…" (Open) | Perceived Authentic Science Questionnaire (Boll, 2013)<br>Analysis of participant response to knowledge with reasoning questions – with use of jargonizer app – http://scienceandpublic.com |
| **Strand 6: Identifying with the scientific enterprise** | | "In the activity, I saw myself as a science person." (Likert)<br>"Specifically …" (Open) | Science Identity Questionnaire Vincent-Ruz & Schunn, 2018)<br>Self-Perception in Science Questionnaire (OECD, 2016) |

## 4.2 Addressing the research questions

The data analysis of the case studies will address the research questions posed in Section 1.1. This data analysis of different types of case study assessment will result in projected benefits to the iSTEM activity designers and researchers (see Table 4.2).

**Table 4.2**. *The data analysis of different types of case study assessment and resulting benefits to iSTEM activity designers and researchers.*

| **Type of Assessment** | **Data Analysis** | **Value to iSTEM Activity Designers** | **Value to Researchers** |
|---|---|---|---|
| Single iSTEM activity or programme | Compare and triangulate data from the different research perspectives<br><br>Correlate results of visitor data with design features of the different iSTEM activities and programmes. | Learn how to design iSTEM activities and programmes that lead to learning outcomes. | Learn what are the learning outcomes of different iSTEM activities and programmes |
| Everyday life -- learning pathways | Correlate results of visitor data with design features of the different iSTEM learning pathways. | Learn how to guide learners through science learning ecosystem to prolong engagement and maximize learning outcomes. | Learn what learning pathways lead to different learning outcomes.<br><br>Understand the differences between a single activity and learning pathways in terms of learning outcomes. |
| With and without Science Chaser as design element | Compare results of visitor data with and without the use of the Science Chaser. | Learn how to use gaming and other techniques to help users navigate their way through learning pathways. | Understand how gaming and other techniques can help users navigate their way through learning pathways. |

Given these projected benefits to both iSTEM activity designers and to researchers, we project that these assessments can contribute to bridging between formal and informal STEM learning (see Table 4.3).

**Table 4.3**. *How assessment of the case studies can contribute to bridging between formal and informal STEM learning*

| **Type of Assessment** | **Contribution of iSTEM activities/programmes to formal STEM learning in schools** | **Contribution of formal STEM learning in schools to iSTEM activities/programmes** |
|---|---|---|
| Single iSTEM activity or programme | Improved design of iSTEM activities/programmes can enrich STEM learning in schools. | The impact of iSTEM activities can be improved by complementary formal activities. |
| Everyday life -- learning pathways | Improved design of learning pathways can enrich STEM learning in schools. | Improved design of learning pathways can enrich iSTEM activities. |
| With and without Science Chaser as design element | Use of gamification can increase learner engagement and learning in learning pathways that involve schools. | Use of gamification can increase learner engagement and learning in iSTEM environments. |

## *4.3 Next steps*

The Surrounded by Project will complete developing its implementation plan (D4.1), based on the methodology and tools developed in this deliverable and the project's research implementation plan (D4.1). The first research cycle is scheduled to take place in 2022-3. Before the beginning of the second research cycle (2023-4), in the summer of 2023, the project team will reflect on the research results and consider making adjustments, in terms of the research tools, the design of the learning pathways by other activity providers for the everyday-life perspective, and the use of the Science Chaser.

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# 6 List of appendices

Appendix I Visitor tracking, timing, and observation sheet

Appendix II Visitor conversations at exhibits form

Appendix III Self-report questions

Appendix IV Semantic differential emotion questionnaire

Appendix V Interest Questionnaire

Appendix VI Nature of Science Questionnaire

Appendix VII Authenticity Questionnaire

Appendix VIII Science Identity Questionnaire

Appendix IX Self-Perception in Science Questionnaire

Appendix X Daily Activity in Science Questionnaire

# Appendix I

# Visitor tracking, timing, and observation sheet

**Instructions for observers:** The following form should be used during the tracking and timing of visitors to a designed environment (e.g., a museum exhibition) in the context-oriented research perspective. Be sure to prepare a map of the exhibition, with all of the exhibits numbered. Use the exhibit numbers in the sheet. You will also need a stopwatch, such as a phone app. Use this stopwatch to record the running times when each exhibit visit begins and ends. When visitors move from one exhibit to another, write the numeral 0 under the exhibit number. For the “engagement level and other behaviours”, use the attached code sheet for Engagement Scale. Add additional behaviours if you think they are interesting to record. At the end of the visit, calculate the time duration of the exhibit and summarize the behaviour of the visitor(s).

<table>
<tr><th colspan="5">Visitor Tracking and Timing Observation Sheet</th></tr>
<tr><td colspan="3">Exhibition: ___________________<br>Date: _______________________<br>Time: _______________________<br>Observer: ___________________</td><td colspan="2">Age group of visitors:<br>YC = young child<br>C = child (6-10)<br>PT = preteen (11-13)<br>T = teen (14-19)<br>A = adult (20-64)<br>S = senior (65+)</td></tr>
<tr><td colspan="5">Describe who is visiting, including the age group (single or multiple visitors):</td></tr>
<tr><td>Exhibit Number</td><td>Running Time (begin)</td><td>Running Time (end)</td><td>Time Duration Exhibit</td><td>Engagement level and other behaviours</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td colspan="5">Summary of behaviour of the visitor(s):</td></tr>
</table>

## Code sheet for Engagement Scale (Falk and Holland, 1991):

| Code | Engagement Level | Description |
|---|---|---|
| 1 | Minimal/Glance | Visitor stops, pauses briefly, and glances at one or more elements, but demonstrates no apparent interest in any particular element or information. |
| 2 | Cursory | Visitor stops, watches/views elements briefly in a cursory way, perhaps casually point to something, and glances at text panels, but demonstrates no apparent interaction with the exhibit. |
| 3 | Moderate | Visitor stops, views several elements of the exhibit with apparent interest, reads some text, and appears somewhat engaged and focused. |
| **4** | **Extensive** | Visitor stops, views most elements of the interactive very intently, reads some text and appears very engaged and focused. |

# Appendix II

# Visitor conversations at exhibits form

**Instructions for observers:** The following form should be used to record conversations at designed environments for the context-oriented research perspective. Use the same map and exhibit numbers used in the Visitor Tracking and Timing Observation Sheet in Appendix I.

| **Form for Visitor Conversations at Exhibits** | | | |
|---|---|---|---|
| Exhibit: ___________________<br>Date: _____________________<br>Time: _____________________<br>Observer: __________________ | | **Age group of visitors:**<br>YC = young child<br>C = child (6-10)<br>PT = preteen (11-13)<br>T = teen (14-19)<br>A = adult (20-64)<br>S = senior (65+) | |
| **Describe who is visiting, including the age group (single or multiple visitors):** | | | |
| **Running Time** | **Exhibit Number** | **Time Duration Exhibit** | **Record conversations and comments of visitors. Use other sheets, if necessary** |
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# Appendix III

## Self-report questions

The following self-report questions will be used by all Case Studies that assess the Person-In-Context Perspective.

These questions will be presented in the Science Chaser in two formats, one for primary school children, and the other for secondary school students. In the former format, the Likert questions will use faces (  ), while in the latter format, these same questions will use numbers only (1=YES! 2 = Yes, 3 = Maybe, 4 = No, 5 =NO!). In the former format, the open-ended questions will be asked in an interview, while in the latter version, these questions can be answered in writing.

| | |
|---|---|
| **Strand 1:** Interest | "The activity was interesting" (Likert)<br>"What I found interesting was …" (open)<br>A question I would like to ask is …(open) |
| **Strand 2:** Knowledge | "I learned something from this activity." (Likert)<br>"What I learned was …" (Open) |
| **Strand 3:** Reasoning | "The activity helped me understand and explain something in science that I couldn't explain before the activity." (Likert)<br>"I could explain that …" (Open) |
| **Strand 4:** Reflection | "The activity helped me understand how scientists work." (Likert)<br>"I understood that scientists work by …" (Open) |
| **Strand 5:** Tools/Language | "In the activity, I used the language and tools of science." (Likert)<br>"I used the following language and tools…" (Open) |
| **Strand 6:** Science Identity | "In the activity, I saw myself as a science person." (Likert)<br>"Specifically …" (Open) |

# Appendix IV

# Semantic Differential Emotion Questionnaire

The Semantic Differential Emotion Questionnaire (Yonai & Blonder, 2022) is a self-report questionnaire to be used in the person-in-context perspective for the outreach programmes, and optional for the other learning contexts.

**Instructions to Learner**: Please mark how you feel, when you think about the activity.

Thanks for your participation!

| **Positive feeling** | **Scale** | **Negative feeling** |
|---|---|---|
| Interest | 1 2 3 4 5 | Boredom |
| Admiration | 1 2 3 4 5 | Disgust* |
| Enjoyment | 1 2 3 4 5 | Suffering* |
| Relief | 1 2 3 4 5 | Anxiety |
| Relaxation | 1 2 3 4 5 | Anger |
| Pride | 1 2 3 4 5 | Shame |
| Hopeful | 1 2 3 4 5 | Hopeless |
| Excitement | 1 2 3 4 5 | Indifference |
| Love | 1 2 3 4 5 | Hate |
| Innovative | 1 2 3 4 5 | Obsolete |
| Cool | 1 2 3 4 5 | Not cool |

# Appendix V

# Interest Questionnaire

The Interest Questionnaire (Linnenbrink-Garcia et al., 2010) will be used to assess strand 1 (being interested in and excited by science) as pre- and post assessment for the participating learners. This Likert questionnaire assesses triggered-situational interest, maintained situational interest, and individual interest based on the 4-stages of interest development (Hidi & Renninger, 2006).

For primary school children, these Likert questions will use faces (  ), while for secondary school students, these same questions will use numbers only (1=YES! 2 = Yes, 3 = Maybe, 4 = No, 5 =NO!).

| **Category** | **Number of items** | **Items** |
|---|---|---|
| 1. Triggered-Situational interest | 4 | 1. I don't like (museum visits/outdoor visits/astronomy visits) very much<br>2. The (museum visits/outdoor visits/astronomy visits) aren't very interesting.<br>3. I enjoy coming to (museum visits/outdoor visits/astronomy visits).<br>4. Usually (museum visits/outdoor visits/astronomy visits) seem to drag forever |
| 2. Maintained situational interest | 5 | 5. I think the field of (biology/chemistry/physics/astronomy) is very boring<br>6. I think what we are learning in (biology/chemistry/physics/astronomy) is important<br>7. I see how I can apply (biology/chemistry/physics/astronomy) to everyday life<br>8. What we are learning in chemistry this year is not important for my future goals<br>9. I think this class is interesting this year |
| 3. Individual interest | 5 | 10. What we are learning in chemistry this year is important for my future goals<br>11. (Biology/chemistry/physics/astronomy) helps me in my daily life outside of school<br>12. I don't like (biology/chemistry/physics/astronomy).<br>13. I'm don't enjoy (biology/chemistry/physics/astronomy)<br>14. Thinking about (biology/chemistry/physics/astronomy) is an important part of who I am |

# Appendix VI

# Nature of Science Questionnaire

The Nature of Science Questionnaire (Conley et al, 2004) will be used to assess strand 4 (reflecting on science) as pre- and post assessment for the participating learners. The Likert questions use a 5-point scale (1- strongly disagree; 5- strongly agree), and all questions were worded to have students focus on the domain of science.

For primary school children, these Likert questions will use faces (  ), while for secondary school students, these same questions will use numbers only (1=YES! 2 = Yes, 3 = Maybe, 4 = No, 5 =NO!).

<u>Source</u>

- Everybody has to believe what scientists say.
- In science, you have to believe what the science books say about stuff.
- Whatever the teacher says in science class is true.
- If you read something in a science book, you can be sure it's true.
- Only scientists know for sure what is true in science.

<u>Certainty</u>

- All questions in science have one right answer.
- The most important part of doing science is coming up with the right answer.
- Scientists pretty much know everything about science; there is not much more to know.
- Scientific knowledge is always true.
- Once scientists have a result from an experiment that is the only answer.
- Scientists always agree about what is true in science.

<u>Development</u>

- Some ideas in science today are different than what scientists used to think.
- The ideas in science books sometimes change.
- There are some questions that even scientists cannot answer.
- Ideas in science sometimes change.
- New discoveries can change what scientists think is true.
- Sometimes scientists change their minds about what is true in science.

<u>Justification</u>

- Ideas about science experiments come from being curious and thinking about how things work.
- In science, there can be more than one way for scientists to test their ideas.
- One important part of science is doing experiments to come up with new ideas about how things work.
- It is good to try experiments more than once to make sure of your findings.

- Good ideas in science can come from anybody, not just from scientists.
- A good way to know if something is true is to do an experiment.
- Good answers are based on evidence from many different experiments.
- Ideas in science can come from your own questions and experiments.
- It is good to have an idea before you start an experiment.

# Appendix VII

## Authenticity Questionnaire

The Authenticity Questionnaire (Boll, 2013) will be used to assess strand 5 (using the tools and language of science) as pre- and post assessment for the participating learners.

For primary school children, these Likert questions will use faces (  ), while for secondary school students, these same questions will use numbers only (1=YES! 2 = Yes, 3 = Maybe, 4 = No, 5 =NO!).

1. I communicated with scientists.
2. I learned how work is done in research.
3. I learned about current important research questions/topics.
4. I learned about employment options in scientific research.
5. I learned about research devices.
6. I learned to interpret and analyze scientific research.
7. In the course I experienced a real scientific environment.
8. I learned about the connection of research to everyday life.

# Appendix VIII

# Science Identity Questionnaire

The Science Identity Questionnaire (will be used to assess strand 6 (identifying with the scientific enterprise) as pre- and post assessment for the participating learners.

For primary school children, these Likert questions will use faces (  ), while for secondary school students, these same questions will use numbers only (1=YES! 2 = Yes, 3 = Maybe, 4 = No, 5 =NO!).

1. I am a science person
2. My family sees me as a science person
3. My friends see me as a science person
4. My teachers see me as a science person

# Appendix IX

# Self-Perception in Science Questionnaire

The Self-Perception in Science Questionnaire (OECD, 2016) can be used to assess strand 6 (identifying with the scientific enterprise) as pre- and post assessment for the participating learners.

For primary school children, these Likert questions will use faces (  ), while for secondary school students, these same questions will use numbers only (1=YES! 2 = Yes, 3 = Maybe, 4 = No, 5 =NO!).

The following questionnaire is appropriate only for secondary school students. The Likert questions use a 4-point scale.

1. I can usually give good answers to test questions on (biology/chemistry/physics/astronomy) topics
2. I learn (biology/chemistry/physics/astronomy) topics quickly
3. (biology/chemistry/physics/astronomy) topics are easy for me
4. I can easily understand new ideas in (biology/chemistry/physics/astronomy)
5. Learning advanced (biology/chemistry/physics/astronomy) topics would be easy for me
6. When I am being taught (biology/chemistry/physics/astronomy), I can understand the concepts very well
7. It would be easy for me to recognize scientific questions in an article about (biology/chemistry/physics/astronomy)

# Appendix X

# Daily Activity in Science Questionnaire

The following Likert-scale items (OECD, 2016) are to be used for the everyday-life research perspective but are optional. When they are used, they should be presented at regular intervals of time, throughout the learner's experience of the learning pathway.

For primary school children, these Likert questions will use faces (  ), while for secondary school students, these same questions will use numbers only (1=YES! 2 = Yes, 3 = Maybe, 4 = No, 5 =NO!).

1. Watch TV programmes about science
2. Borrow or buy books on scientific topics
3. Visit web sites about scientific topics
4. Read science magazines or science articles in newspapers
5. I attend a science club
6. I perform simulationsof technical processes using computer software or by means of a virtual laboratory.
7. I visit the Internet websites of environmental organizations. I follow blogs or microblogs (e.g., on Twitter, status updates on Facebook) of organizations from the fields of science, the environment or ecology.
8. I visit the websites of environmental organizations.
9. I follow blogs or microblogs (e.g., on Twitter, status updates on Facebook) of organizations from the fields of science, the environment or ecology.