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Surrounded by Science

# *Learning Paths towards Science Proficiency*

*Research and Innovation Action in the European Union's Horizon 2020 Programme*
*Grant Agreement no. 101006349*

# Deliverable 2.2

## Surrounded by Science Key Characteristics and Matrices

| | |
|---|---|
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## Legal Notices

# Executive Summary

This document presents the approaches and the results of the task undertaken in WP2 of the Surrounded by Science project to identify key design characteristics and create matrices with success criteria. To ensure evidence-based results, two approaches were used: bottom-up (interviewing different groups of stakeholders) and top-down (reviewing literature). In total, 219 stakeholders were interviewed: 51 activity providers, 66 teachers, and 102 participants of iSTEM activities. They came from 20 different countries and talked about activities from the three different learning environments that are distinguished in the project (outreach programmes, designed environments, and technology and media products). Based on the interviews, a large table was constructed in which each activity was listed and described in terms of what kind of activity it was, which goals for science proficiency were set, and what features the provider of the activity found key in designing them.

From this large table as well as from checking existing repositories covering iSTEM learning activities in Europe, activity types were identified for each learning context. In total, 14 activity types were identified: five activity types were identified for outreach programmes, three activity types were described for designed environments, and six activity types were presented for technology and media products. Next, a list of key design characteristics was identified for each learning context. This was based on the interviews as well as on literature. Two general characteristics that can be seen as pre-requisites for any iSTEM learning activity were found: providing scientifically correct information and being interesting for participants. In addition, seven characteristics were identified for outreach programmes: connection to real life, choice of a relevant topic, encouraging curiosity/ questioning/ inquiry, personal experience/ interest-based, interactivity, collaboration/ dialogue with peers, and age- and ability-appropriate language and tasks. For designed environments, nine characteristics were identified: connection to real life, choice of topic, encouraging curiosity/ questioning/ inquiry, combining visual, audial and kinaesthetic information and activities, active involvement/ interactivity, visually attractive materials, authentic materials, collaboration/ family learning, and age- and ability-appropriate language. Finally, six characteristics were formulated for technology and media products: accessible/ easy to use, connection/ relevance to real life, encouraging curiosity/ questioning/ inquiry, visually attractive (design), manageable and engaging way of presenting information (for media products), and interaction with the audience/ active engagement (for media products).

The identified activity types and key design characteristics were input for the matrices that were created for each context in which key design characteristics and their success criteria were presented for all activity types.

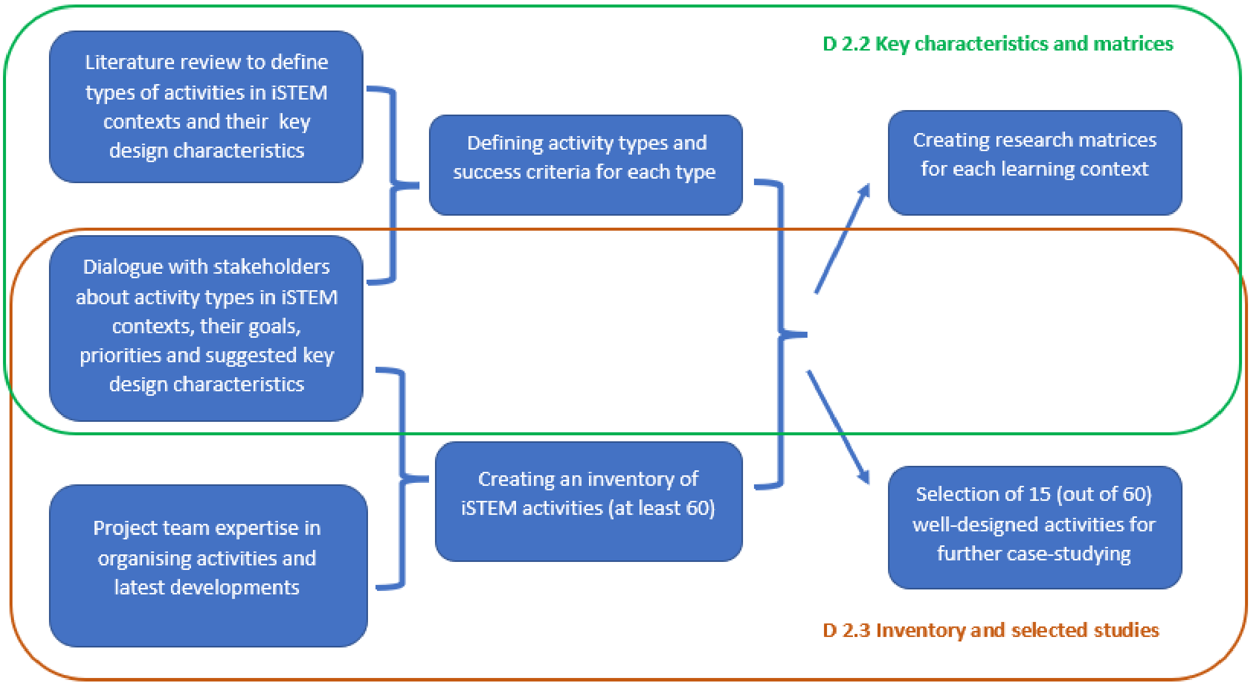
# Table of Contents

# 1 Introduction

This deliverable presents the key design characteristics and their success criteria that were identified for different iSTEM activities in different learning contexts. They are a result of Work Package 2 work with different groups of stakeholders and a literature review.

The goal of this document is to introduce the process of identifying these design characteristics (or key design features) and success criteria that was used by the project: from the ways to collect data to the results. This deliverable is closely connected to D2.3 *Inventory of Activities and Selected Case Studies* as it influences the selection of case studies. Figure 1 shows a diagram of the intertwined process of collecting the information for tasks presented in D2.2 and D2.3.

**Figure 1.** *Connection between different tasks and deliverables within WP2*




The results of this Work Package 2 work will inform work of Work Package 3 in terms of developing the Science Booster, Work Package 5 in terms of developing the assessment scheme, and Work Package 4 in terms of conducting research activities.

Chapter 2 presents methods that were used to complete the task: a description is given of the approaches and procedure to collect data, information is given about participants in data collection sessions, and the plan for data analysis is provided.

Chapter 3 shows the first results by introducing activity types identified for each learning context – outreach programmes, designed environments, and technology and media products. These activity types will be used in the project from now on.

Key design characteristics for each learning context are given in Chapter 4 together with the methods used to identify them, with success criteria for these characteristics being presented in Chapter 5.

The last chapter (Chapter 6) provides a conclusion to this document by summarising what has been done and how this work will be used by other work packages.

# 2 Methods to identify key design characteristics

This chapter presents how key design characteristics for all three learning contexts used in the project – outreach programmes, designed environments, and technology and media products – were identified.

## *2.1 Approaches to collect data*

The aim of the project was to identify key design characteristics of informal STEM (iSTEM) learning activities (for more information about iSTEM activities see D2.1). Two approaches were used to collect data. The first was a bottom-up approach that introduced practitioners' views on which key design characteristics are used and named by different groups of stakeholders (i.e., activity providers, teachers, and visitors/participants). The other approach was a top-down one and presented which key design characteristics can be identified by the literature and theories, and are supported by research. The combination of these two approaches allowed the project team to support the data collected from practitioners by literature, and to check theoretical assumptions with actual stakeholders.

The *bottom-up approach* was implemented by conducting a series of interviews with three groups of stakeholders: activity providers, school teachers, and participants of iSTEM learning activities. In these structured interviews (i.e., interviews with a pre-defined set of questions), they were asked about design characteristics that they value in different iSTEM activities and their reasons for that.

Activity providers were asked about specific activities they designed and were invited to name all the design characteristics that they used in the design and explain why they find them important. Teachers were asked more general questions about types and characteristics of iSTEM learning activities that they value and their explanations for that. From these more general questions, the information about design characteristics was extracted. Participants of a specific activity were asked about their experience (e.g., what they liked most and least), so their perception of design characteristics could be extracted from that. Table 1 presents the questions about design characteristics used for the interviews with different groups of stakeholders. The full text of interviews of different groups of stakeholders is presented in Appendices III-V.

**Table 1.** *Interview questions about key design characteristics for different groups of stakeholders*

| Group of stakeholders | Questions |
|---|---|
| Activity providers | • What characteristics did you consider important while designing the activity? By design characteristics we mean things like the level of interactivity, control of the experience by the visitor, connection to real life, etc.<br>• Why do you find them important? |
| Teachers | • What do you see as an added value of iSTEM activities (that you are not engaged in as a teacher)?<br>• What kind of iSTEM activities do you find beneficial for your students? Why? |
| Visitors | • What did you like most about this [exhibition]? Why?<br>• What was the least interesting? Why?<br>• What are the three words that describe how you felt during the experience that you had at the [exhibition]? |

The interviews covered more topics than just the design characteristics, as these interviews were also used as input for other project tasks. The other topics are not described in the current deliverable.

The *top-down approach* was based on studying scientific literature covering design of iSTEM learning activities. This means that the project team looked for articles published in scientific peerreviewed journals dealing with instructional design and design principles for developing informal learning activities. The aim of the literature search was to find evidence-based support for design characteristics that were mentioned by stakeholders. This was done by looking at scientific studies that reported about the effectiveness of these specific design characteristics in out-of-school science activities. In addition, during this search, we also found some design characteristics that were not mentioned by activity providers. These characteristics were considered valuable additions based on the fact that they resulted from scientific studies, therefore, they were added to the final list.

## *2.2 Participants*

Participants were recruited via the existing networks of the project members as well as by openly approaching different stakeholders.

When planning the interviews, the project team aimed at representing the existing variety of out-of-school activities as good as possible, therefore, interviews were conducted in different countries and with different categories of stakeholders within one group. For the activity providers group, such categories meant providers of activities of different learning contexts and covering different STEM areas; for teachers, it meant interviewing both primary and secondary school teachers in different countries; and for visitors and participants, it meant participants of different types of activities in different countries. Table 2 presents an overview of conducted interviews. With 219 interviews, the Key Performance Indicator associated with this task – involving 200 stakeholders – was reached.

**Table 2.** *Overview of interviews conducted with different groups of stakeholders*

| **Stakeholders** | **Conducted interviews** | **Countries** | **Variation** |
|---|---|---|---|
| Activity providers | 51 | Italy (15),<br>Portugal (12),<br>Israel (12),<br>The Netherlands (5),<br>Greece (2),<br>Germany (2),<br>Finland (1),<br>Sweden (1),<br>USA (1) | Activities from all three learning contexts:<br>• outreach programmes (27),<br>• technology/media products (13),<br>• designed environments (11)<br>Covered STEM areas: astronomy, biology, chemistry, design, ecology, engineering, mathematics, physics, technology.<br>It is not possible to provide numbers as many activities integrate several STEM areas. |
| Teachers | 66 | Greece (17),<br>Israel (16),<br>Portugal (7),<br>Italy (6),<br>The Netherlands (5),<br>France (2),<br>Spain (2),<br>Croatia (1),<br>Turkey (1),<br>Germany (1),<br>Denmark (1),<br>Sweden (1),<br>UK (1),<br>Czech Republic (1),<br>Poland (1),<br>Romania (1),<br>Albania (1) | Teachers of different levels of education:<br>• secondary school STEM teachers (55),<br>• primary school teachers (9),<br>• pre-school teachers (2) |

| | | | |
|---|---|---|---|
| | | Serbia (1) | |
| Participants | 102 | The Netherlands (43),<br>Italy (39),<br>Portugal (20) | Visitors/participants of different types of activities:<br>• outreach programmes (63),<br>• designed environments (39) |

## 2.3 Procedure

*Activity providers* were interviewed individually either at a physical meeting or online (using Microsoft Teams or Zoom) and the talk took 45-60 minutes. Before the start of an interview, written consent was obtained from the interviewee (see Appendix I). An active form of consent was chosen as interviews were recorded to enable later coding and analysis of the data. However, only the interviewer had access to this recording. While coding, the data were anonymised and in this way shared with the project team. If possible, interviews were conducted in the native language of the activity provider, otherwise they were in English.

Interviews with *teachers* were also conducted either offline or online and lasted around 30 minutes. Most interviews were individual, but some were conducted with a group of teachers (2-4 participants) for practical reasons; however, answers of each teacher were noted and analysed separately. Similarly to activity providers, teachers were asked to provide active consent prior to the interview (see Appendix II). These interviews were also recorded and followed the same coding procedure as the interviews with activity providers – only anonymised data were shared with the project members. The choice of language followed the same approach as with activity providers.

Interviews with *visitors/participants of out-of-school activities* were conducted offline after they engaged in the activity, either orally by an interviewee or by means of a paper-and-pencil questionnaire that they needed to complete. Completing this took 7-10 minutes. All visitors' data were collected anonymously, so no written consent was obtained, however, participation in the interviews was fully voluntarily. All interviews and questionnaires were in the native language of the country, in which they took place.

## 2.4 Plan for the data analysis

First, data of the interviews with activity providers were prepared for the analysis: they were translated into English, anonymised, and presented in one large table. This table covered all data collected during the interviews, including the goals of the activity in terms of science proficiency (SP) and the data on the key design characteristics (see Appendix III, Figure 8 for the strands of science proficiency). For the current deliverable, only these columns will be used and presented. The reason for also including the goals in terms of science proficiency is that these goals influence the design features for that activity. For example, the design of an activity with the goal to engage participants in scientific reasoning about a scientific phenomenon differs from the design of an activity aiming at getting visitors interested in this phenomenon. The number of columns related to the key design features depended on the amount of key design features an activity provider mentioned. Table 3 presents the relevant columns as well as the data of one of the activities. The same was done with the data of the interviews with the teachers and the data of the visitors/participants of out-of-school science activities resulting in similar tables.

**Table 3.** *Presentation of the interview data of activity providers about key design characteristics with an example*

| ID number | Activity type | Goals in terms of SP | Key design feature 1 | Justification/ explanation | Key design feature 2 | Justification/ explanation | … |
|---|---|---|---|---|---|---|---|
| UT_act_5 | workshop | understanding scientific content and knowledge | working with authentic material | it is a purpose of a museum to show real things | stimulating thinking process | encourage students to search for answers rather than being given a right answer | |

Note: SP – science proficiency

Second, activity types were identified based on how activity providers categorised their activities and the description they provided. After that, the created list of activities was compared with activities in existing repositories to make sure that no types are missing. The process of identifying activity types is described in more detail in Chapter 3.

Third, for each activity type, all design characteristics mentioned by activity providers were collected and summarised to group similar characteristics together. Then the same was done for all activities within one learning context.

Fourth, literature review was conducted to study what key design characteristics were identified as successful either by different learning theories or by various experiments. For each key design feature based on the interview data, literature support was looked for. To do so, articles about studies conducted in a specific learning context (i.e., outreach programmes, design environments, and technology and media products) were checked to see if they provide the same characteristics as suggested by activity providers. If any characteristics were not mentioned by activity providers but were identified by literature, they were added to the list.

Fifth, data from teachers' interviews were used to support identified key characteristics. In other words, it was checked if what teachers found important was also included in the list of key design characteristics, and how many key design characteristics were mentioned by teachers.

Finally, the data from visitors' interviews were used similarly to the data from teachers' interviews, even though this source of data gave the least amount of information due to brief and less obtrusive interviews.

Following these steps, the project team aimed at triangulating the final list of key design characteristics by including the perspective of practitioners (activity providers), scientists (literature review) and users (teachers and visitors).

# 3 Activity types

This chapter presents the process and the results of identifying types of iSTEM learning activities for the three learning contexts – outreach programmes, designed environments, and technology and media products.

For all learning contexts, activities identified by activity providers that referred to the same action, but were formulated differently were grouped to create a general type. Several examples of this process for different contexts are given in Figures 2-4.

**Figure 2.** *An example of grouping activities included in the outreach programmes learning context*

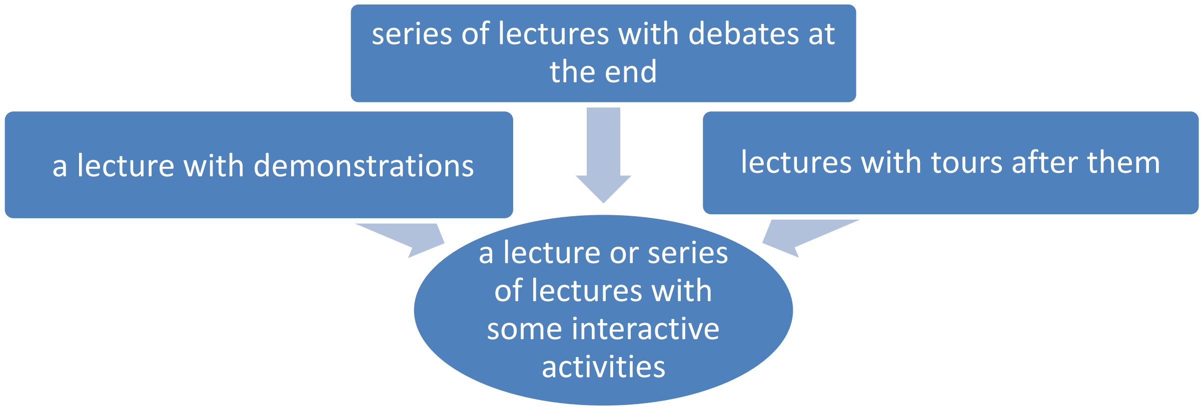



**Figure 3.** *An example of grouping activities included in the designed environments learning context*

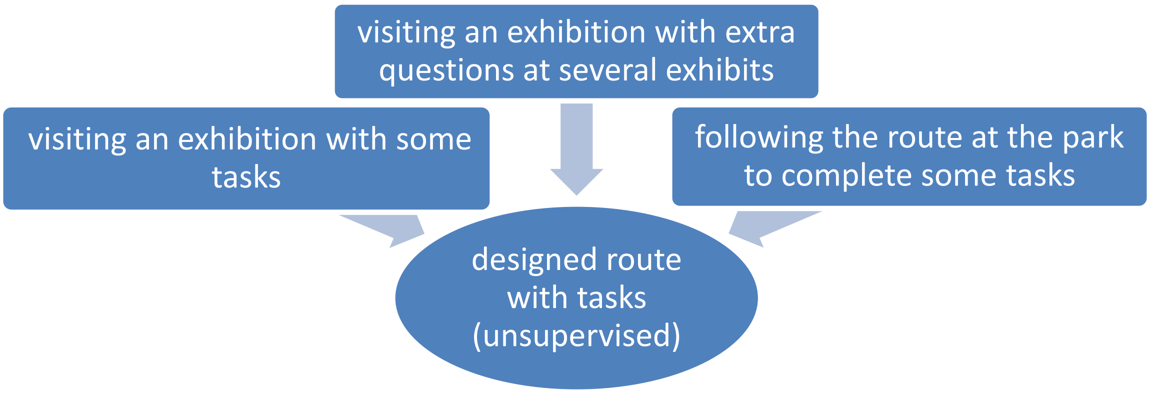
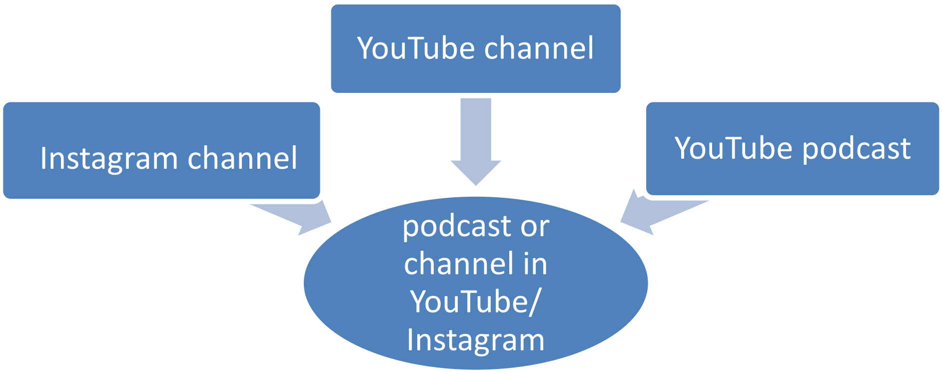



**Figure 4.** *An example of grouping activities included in the technology and media products learning context*



The results of excluding any overlap while still making a clear distinction between similar activities are presented below, separately for each learning context.

## 3.1 Outreach programmes

Scientific outreach programmes refer to coherent programmes designed and organised by out-of-school organisations and including a curriculum that addresses the main activities of the organisation.

The grouping of similar-by-nature activities resulted in 5 activity types. See Table 4 for the types and their definitions. In order to make the differences between the activity types even clearer, remarks have been added in which differences with the other types are made explicit.

**Table 4.** *Activity types for outreach programmes and their definitions*

| Activity type | Definition | Remarks |
|---|---|---|
| 1. Summer or afterschool science camp or club | A series of regular meetings with different topics and activities included. | Different from science and technology projects: covers different topics and provides more guidance.<br>Different from workshops: more and regular meetings.<br>Different from lectures: more meetings and more active participation. |
| 2. Lecture or a series of lectures with some interactive activities (e.g., debates, tours, demonstrations, experiments) | An activity that has a goal of providing information about a specific topic with a small interactive part. | Different from a workshop or a series of workshops: much less interactivity. |
| 3. Science and technology projects | A series of meetings devoted to a specific goal – producing something and presenting it to public. | Different from summer or afterschool science camp or club: focuses on one concrete topic, has a clear end moment, includes presenting final products to an audience.<br>Different from workshop or a series of workshops: includes other types of actions (collecting data, conducting needs-analysis, etc.) and a (possible) longer period. |
| 4. Workshop or a series of workshops | A hands-on-focused activity (organised by any science-engagement institution), which uses any type of authentic materials, equipment, or technology. | Different from lecture or a series of lectures: more active participation and hands-on experience. |
| 5. Scenario-based activity (e.g., escape room, treasure hunt) | An activity with a pre-defined scenario for a pre-defined group of participants. | Different from designed route with tasks: suggests a pre-defined group and provides more supervision to complete the route. |

## 3.2 Designed environments

Designed environments refer to environments designed by out-of-school organisations, that aim to provide specific information or experiences and which are related to family or leisure.

The final list of activities and their definitions are given in Table 5.

**Table 5.** *Activity types for activities in designed environments and their definitions*

| Activity type | Definition | Remarks |
|---|---|---|
| 1. Guided tour | A group tour with a guide providing information. | N/A |
| 2. Unguided visit to an exhibition with exhibits of various levels of interactivity | A free walk in a science-engagement institution following users' interests, during which they interact with freely chosen exhibits based on instructions provided next to the exhibits. | N/A |
| 3. Designed route with tasks (unsupervised) | A walk in a science-engagement institution following a specifically designed route with tasks. | Different from a scenario-based activity, like a treasure hunt: no pre-defined group, can be stopped at any moment. |

## *3.3 Technology and media products*

Technology and media products refer to on- and offline products that out-of-school science organisations develop for the public, and which rely on the expertise and the responsibility of the organisations.

In this context, not so much grouping was done because of broadness of the area of these products. For the same reason, no real overlapping between activities were registered, so no clarification remarks were needed. The final list of activities and their definitions are given in Table 6.

**Table 6.** *Activity types for technology and media products and their definitions*

| Activity type | Definition | Remarks |
|---|---|---|
| 1. website with various activities | Activities can include tutorials, MOOCs, reading materials, quizzes, etc. | N/A |
| 2. any printed offline products | Any printed products with science content, such as comic books, leaflets, workbooks, etc. | N/A |
| 3. radio and tv programmes, podcasts, channels in social media | Activities using any media channels to share video, audio or written information with science content. | N/A |
| 4. online exhibition | An exhibition developed by a science-engagement organisation and hosted on its website | N/A |
| 5. digital scenario-based activity | Activities can include escape room, treasure hunt, etc. | N/A |
| 6. dissemination events | Events with the aim to informing public about the results of projects, inventions, etc. | N/A |

## *3.4 Comparison with existing repositories*

After identifying activity types for all three contexts, a broad research on existing activities was conducted by studying repositories of recently completed European projects that looked at the development of iSTEM activities in Europe. The repositories created by projects with different goals were included: SySTEM 2020, CREATIONS, PATHWAY, COMnPLAY and ESCITE network. The SySTEM 2020 project (https://system2020.education/the-map/) mapped iSTEM initiatives beyond the classroom that are designed for learners aged 9-20, many of whom come from minority, economically disadvantaged and migrant communities. The CREATIONS project (http://creations-project.eu/resources/creations-resources/) focused on STEAM activities, with an "A for Art" added to the traditional STEM framework. Inspired by that, we looked at iSTEM activities that represent scientific concepts in innovative and imaginative ways. The aim of the PATHWAY project (http://pathway.ea.gr/content/pathway-best-practices) was to develop a standard-based approach to teaching science by inquiry by various means, including the connection of out-of-school science learning and science learning in schools. We studied the types of activities that the project identified as complementing formal schooling. The COMnPLAY project (https://comnplayscience.eu/) aimed to better understand the ways that STEM/STEAM learning activities – particularly related to coding and making -- can engage learners and develop their technological skills in out-of-school settings. Therefore, we used the COMnPLAY project's Inventory of Practices (https://comnplayscience.eu/app/practice) to check the types of technology-oriented STEM learning activities. The European network of science centres and museums ECSITE (https://www.ecsite.eu/) allowed to check the types of activities provided by the members of the organisation.

The aim of this research was to make sure that the list of activities that we identified also covers the types of activities that were reported by other projects, activity providers, and researchers. The types of activities presented in repositories and their frequency are shown in Table 7.

**Table 7.** *Activity types in the repositories*

| Activity type | Number of mentioning |
|---|---|
| Contest | 7 |
| Laboratory | 5 |
| Student training | 12 |
| Teacher training | 39 |
| Online activity | 6 |
| Workshop | 105 |
| Event (conference, festival, seminar included) | 55 |
| Theatre performance | 3 |
| Exhibition | 1 |
| Out-of-school lesson | 7 |
| Masterclass | 7 |
| Science centre/science museum | 123 |
| Natural history museum | 18 |
| Research body/university | 25 |
| Private company/consultancy | 36 |
| Professional network | 6 |
| Club | 2 |
| Project | 4 |
| Total number of activities listed | 461 |

From the table, it becomes clear that the way in which activities are defined in these repositories is different from the way they are defined in the current project. In order to see whether our activity types covered the activity types mentioned in the repositories, the first step was to leave out those items that are either beyond the scope of the Surrounded by Science project (i.e., student training, teacher training, and out-of-school lesson given by the school teacher), or provide other information than an activity (i.e., private company/consultancy, and professional network). The second step was to attempt to convert the activity types presented in the repository to our identified activity types and to see whether all activities were covered. Although we do not know for sure what the activities from the repository exactly entail, we were able to make a possible transition. This confirms that our list is complete and covers all prevailing types of existing activities and that we do not have to add new activity types. The result of both steps is shown in Table 8.

**Table 8.** *Activity types in the repositories and their possible transition to the identified activity types in the current project*

| **Activity type** | **Possible transition to the identified activity types** |
|---|---|
| Contest | Depending on the organisation, target group, and tasks, it can be a science club or a science and technology project |
| Laboratory | Depending on the level of interactivity, it can be a workshop (in a laboratory) or a lecture with demonstrations (in a laboratory) |
| Online activity | Website |
| Workshop | Workshop |
| Event (conference, festival, seminar included) | Depending in a specific type of the event and its goals, it can be a lecture, a workshop or a dissemination event |
| Theatre performance | Depending on the way of implementation, it can be a radio or tv programme, or a lecture |
| Exhibition | Guided or unguided visit |
| Masterclass | Workshop or lecture |
| Science centre/science museum | Guided or unguided visit |
| Natural history museum | Guided or unguided visit |
| Research body/university | Workshop or lecture (in a research body/university) |
| Club | Science club |
| Project | Science and technology project |

# 4 Key design characteristics

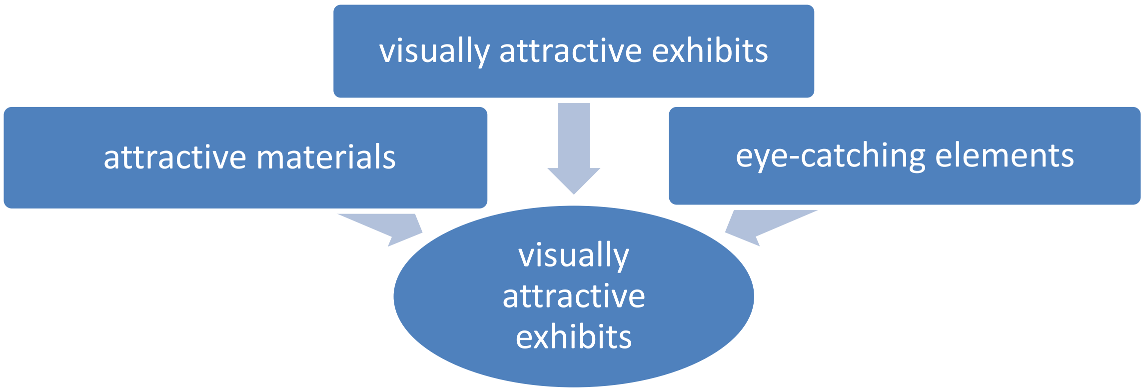
This chapter presents the key design characteristics, with identification of these characteristics being the result of the analysis of the interview data and literature.

The original intention was to identify key design characteristics for each activity type within a specific context. However, in the process of data analysis, it became clear that design characteristics of different activity types in the same context overlap so much, that they can be seen as characteristics of the context rather than of an activity type. Therefore, in the sections following, the key design characteristics for each context (outreach programmes, designed environments, and technology and media products) are presented.

The process of working with the interview data of activity providers was similar to the process of identifying activity types described in the previous chapter and is described below. The starting number of design characteristics mentioned by activity providers differed per context and was quite big: outreach programmes – 28, designed environments – 24, technology and media products – 25.

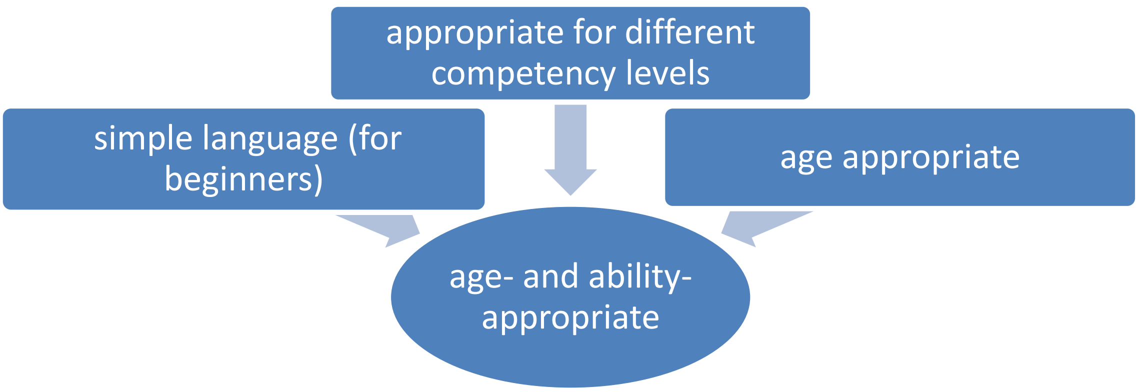
First, the different formulations of the same by nature design characteristics were identified and grouped. An example of such grouping is shown in Figure 5.

**Figure 5.** *Grouping similar formulations*




Second, a deeper look was taken at the grouped activities to see if some of them belong together or present different examples of a bigger overarching design feature. An example of this aggregating process is presented in Figure 6.

**Figure 6.** *Aggregating key design characteristics*




Finally, these design characteristics were checked for being supported by literature, as well as being mentioned by teachers and/or participants. Design characteristics that were not mentioned by activity providers, but were found in the literature during the support search, were also added to the list. The results of these steps for each learning context are presented next.

## *4.1 General key design characteristics*

During the analysis, it became apparent that there are two design characteristics that can be seen as pre-requisites for any iSTEM learning activity, regardless of the context. They are described here separately as they apply to all activities and contexts. These general characteristics and their explanations are given in Tables 9 and 10 respectively. Moreover, Table 9 also includes an indication if these design characteristics are supported by literature (with a reference to example articles in the reference list), and mentioned by school teachers and visitors that were interviewed.

**Table 9.** *General design characteristics for iSTEM learning activities*

| Design characteristics | Supported by literature | Mentioned by teachers | Mentioned by visitors |
|---|---|---|---|
| 1. Providing correct scientific information | Yes, # 4 | Yes | Yes |
| 2. Being interesting and fun for participants | Yes, # 16, 20 | Yes | Yes |

**Table 10.** *Explanation of the general design characteristics for iSTEM learning activities*

| Design characteristics | Explanation |
|---|---|
| 1. Providing correct scientific information | The activity should provide information that is scientifically correct. It is important not only because incorrect scientific information may lead to misconceptions (which is the opposite of any learning activity), but also because it may lead to general disbelief in science if the right information is discovered later. |
| 2. Being interesting and fun for participants | The activity should engage and excite participants by science content. Making an iSTEM learning activity fun for its participants appeals to the nature of informal learning. In this context, it is interest what attracts visitors and motivates them to participate, therefore without it no further interaction is possible. |

## *4.2 Outreach programmes*

Table 11 presents the key design characteristics for outreach programmes identified as a result of the interviews with activity providers. The table also includes indication of literature support (with the corresponding number from the reference list), and mentioning by school teachers and visitors.

**Table 11.** *Design characteristics for outreach programmes*

| Design characteristics | Supported by literature | Mentioned by teachers | Mentioned by visitors |
|---|---|---|---|
| 1.Connection to real life | Yes, # 3, 12 | Yes | Yes |
| 2. Choice of a relevant topic | Yes, # 6, 12 16, 20 | Yes | |
| 3. Encouraging curiosity/ questioning/ inquiry | Yes, # 6, 7, 12, 16, 19, 20 | Yes | Yes |
| 4. Personal experience/ interest-based | Yes, # 7, 12, 16, 19, 20 | Yes | Yes |
| 5. Interactivity | Yes, # 12, 19 | Yes | Yes |
| 6. Collaboration/ dialogue with peers | Yes, # 2 | Yes | Yes |
| 7. Age- and ability-appropriate language and tasks | Yes, # 6 | Yes | |

The explanation of each design characteristic is given in Table 12.

**Table 12.** *Explanation of the design characteristics for outreach programmes*

| Design characteristics | Explanation |
|---|---|
| 1.Connection to real life | The activity should be presented in a way that shows a clear connection between the science knowledge and technology behind the activity and everyday-life situations. |
| 2. Choice of a relevant topic | The topic of the activity should contribute to the development of science proficiency and complement existing formal learning activities, for example, by: |
| | presenting several STEM areas together and possibly connecting them, and/or |
| | covering topics (partly) beyond school curricula, and/or |
| | introducing skills useful for participants (either directly or in the future). |
| 3. Encouraging curiosity/ questioning/ inquiry | The activity stimulates a curious attitude towards shown phenomena and other related phenomena in everyday life, and a critical way of studying such phenomena, for example, by: |
| | being presented with challenging and interesting problems and/or |
| | being encouraged to look for answers, not being provided with answers, and/or |
| | being involved in an (authentic) research experience/ cycle using authentic materials or equipment, and/or |
| | focusing on the process of studying, not the product. |
| 4. Personal experience/ interest-based | The activity is chosen based on the personal interests and allows participants to get a personal experience while interacting with scientific phenomena, for example, by |
| | experiencing emotional connection between science and life, and/or |
| | working with visually attractive and interesting materials |
| | connecting to real scientists, and/or |
| | feeling ownership of learning/ created products. |
| 5. Interactivity | The activity assumes active participation, which can be reached by: |
| | providing hands-on experience (for science camps, projects, workshops, and scenario-based activities) |
| | interacting with the audience and including interactive activities (for lectures) |
| | using a game format/ gamification elements. |
| 6. Collaboration/ dialogue with peers | The activity gives space and encourages collaboration and/or dialogue with peers. |
| 7. Age- and ability-appropriate language and tasks | The activity is designed using age- and ability appropriate language and levels of tasks. |

## *4.3 Designed environments*

Similarly to outreach programmes, key design characteristics were identified for designed environments. They are presented in Table 13, together with an indication of support by literature, and recognition by teachers and visitors. The numbers correspond to the studies in the reference list.

**Table 13.** *Design characteristics for designed environments*

| Design characteristics | Supported by literature | Mentioned by teachers | Mentioned by visitors |
|---|---|---|---|
| 1. Connection to real life | Yes, # 4 | Yes | |
| 2. Choice of topic *(based on literature)* | Yes, # 11, 14 | Yes | Yes |
| 3. Encouraging curiosity/ questioning/ inquiry | Yes, # 18 | Yes | Yes |
| 4. Combining visual, audial and kinaesthetic information and activities | Yes, # 13 | Yes | Yes |
| 5. Active involvement/ interactivity | Yes, # 6, 8, 9, 11 | Yes | Yes |
| 6. Visually attractive materials | Yes, # 21 | Yes | |
| 7. Authentic materials | Yes, # 5 | Yes | Yes |
| 8. Collaboration/ family learning | Yes, # 8, 9, 10, 21 | Yes | |
| 9. Age- and ability-appropriate language | Yes, # 8, 11, 14 | Yes | Yes |

Explanations of design characteristics are presented in Table 14.

**Table 14.** *Explanation of the design characteristics for designed environments*

| Design characteristics | Explanation |
|---|---|
| 1. Connection to real life | The activity shows the connection between demonstrated scientific phenomena and technology and everyday-life situations, including stimulating emotional reactions. |
| 2. Choice of topic *(based on literature)* | The topic of the activity should contribute to the development of science proficiency, for example, by: |
| | presenting several STEM areas together and possibly connecting them, and/or |
| | covering topics (partly) beyond school curricula. |
| 3. Encouraging curiosity/ questioning/ inquiry | The activity stimulates curious attitude towards shown phenomena and other phenomena in everyday life, and critical way of studying such phenomena, for example, by: |
| | getting participants excited about shown phenomena and technology, and/or |
| | providing extra information (from a guide), and/or |
| | demonstrating curiosity in an exhibition (the story behind it). |
| 4. Combining visual, audial and kinaesthetic information and activities | The activity uses several channels of information (e.g., see and listen) for a richer experience. |
| 5. Active involvement/ interactivity | The activity assumes participants interaction with (some of the) exhibits and active involvement, for example, by: |
| | using game format/ gamification, and/or |
| | using affordances in the exhibits that make clear that visitors can interact with them. |
| 6. Visually attractive materials | The activity includes materials and/or exhibits that are eye-catching and attract attention. |
| 7. Authentic materials | The activity (mainly) uses authentic materials and exhibits. |

| | |
|---|---|
| 8. Collaboration/ family learning | The activity gives space and encourages collaboration between family or group members (for unguided visits and designed routes with tasks). |
| 9. Age- and ability-appropriate language | The activity can address different age- and ability-levels. |

## *4.4 Technology and media products*

In this section, design characteristics for technology and media products are presented and explained. Table 15 gives a list of these features with support from literature and mentioning by teachers. Compared to the two other contexts, there is not much teachers' support shown in the table. This is caused by the fact that these activities were mentioned by teachers very rarely as they mostly talked about outreach programmes and designed environments. No users of technology or media products were interviewed, therefore, visitors' support is not included in this table.

**Table 15.** *Design characteristics for technology and media products*

| **Design characteristics** | **Supported by literature** | **Mentioned by teachers** |
|---|---|---|
| 1. Accessible/ easy to use | Yes, # 17 | |
| 2. Connection/relevance to real life | Yes, # 4 | Yes |
| 3. Encouraging curiosity/ questioning/ inquiry *(based on literature)* | Yes, # 4 | Yes |
| 4. Visually attractive (design) | Yes, # 15 | |
| 5. Manageable and engaging way of presenting information (for media products) | Yes, # 1 | |
| 6. Interaction with the audience/ active engagement (for media products) | Yes, # 1 | |

Table 16 presents the explanation of these design characteristics.

**Table 16.** *Explanation of the design characteristics for technology and media products*

| **Design characteristics** | **Explanation** |
|---|---|
| 1. Accessible/ easy to use | The product is intuitive to use and is accessible using different devices |
| 2. Connection/ relevance to real life | The product shows the connection between demonstrated scientific phenomena and technology and everyday-life situations, including connection to real people stories. |
| 3. Encouraging curiosity/ inquiry/ questioning *(based on literature)* | The activity stimulates a curious attitude towards presented phenomena and other phenomena in everyday life. |
| 4. Visually attractive (design) | The design of the product is visually attractive. |
| 5. Manageable and engaging way of presenting information (for media products) | Information is presented in an easy and engaging way, including, for example: |
| | story-telling, and/or |
| | humour, and/or |
| | connection to real people |

| | |
|---|---|
| 6. Interaction with the audience/ active engagement (for media products) | The activity includes interaction with the audience by asking questions, allowing to comment, etc. |

# 5 Matrices with success criteria

This chapter presents the identified design characteristics with an indication how these characteristics should be implemented successfully. These matrices are based on the results presented in Chapters 3 (activity types) and Chapter 4 (key design characteristics). Each subsection covers one learning context.

## *5.1 Outreach programmes*

Table 17 presents the matrix with key design characteristics and their success criteria for the activity types of outreach programmes.

**Table 17.** *Success criteria matrix for outreach programmes*

<table>
<tr><th></th><th>Connection to real life</th><th>Choice of a relevant topic</th><th>Encouraging curiosity/ questioning/ inquiry</th><th>Personal experience/ interest-based</th><th>Interactivity</th><th>Collaboration/ dialogue with peers</th><th>Age- and ability-appropriate language and tasks</th></tr>
<tr><td>summer or afterschool science camp or club</td><td rowspan="5">shows clear connection between science (and/ or technology) and everyday life</td><td rowspan="5">complements formal education by presenting topics outside school curricula or using interdisciplinary-nary approach</td><td rowspan="5">provides authentic research experience of solving challenging problems</td><td rowspan="5">establishes a personal connection to science and/ or scientists</td><td rowspan="4">provides hands-on experience and/or game elements</td><td rowspan="5">encourages collaboration and discussion with peers</td><td rowspan="5">fits the age- and ability-target groups and/or allows adjustments for different level</td></tr>
<tr><td>science and technology projects</td></tr>
<tr><td>a workshop or a series of workshops</td></tr>
<tr><td>scenario-based activity</td></tr>
<tr><td>a lecture or a series of lectures with some interactive activities</td><td>interaction with audience and interactive activities</td></tr>
</table>

## 5.2 Designed environments

Table 18 gives the matrix with key design characteristics and their success criteria for the activity types of designed environments

**Table 18.** *Success criteria matrix for designed environments*

| | Connection to real life | Choice of a relevant topic | Encouraging curiosity/ questioning/ inquiry | Combining visual, audial and kinaesthetic information and activities | Active involvement/ interactivity | Visually attractive materials | Authentic materials | Collaboration/ family learning | Age- and ability-appropriate language |
|---|---|---|---|---|---|---|---|---|---|
| guided tour | shows connection between demonstrated scientific phenomena and everyday life, including emotional connection | presents scientific phenomena as connections between different STEM areas, and/or beyond school programme | stimulates curious attitude towards demonstrated phenomena by challenging visitors' views, providing extra information and/or getting them excited and inspired | uses several channels of information | includes interactive and/or gamification elements, which are clear and easy to interact with | exhibits and materials attract attention | uses (mainly) authentic materials and exhibits | n/a | Is clear and understandable for different age- an ability-levels |
| unguided visit to an exhibition with exhibits of various levels of interactivity | | | | | | | | Gives space and encourages collaboration within a group or a family | |
| designed route with tasks (unsupervised) | | | | | | | | | |

## 5.3 Technology and media products

Similarly to the previous contexts, Table 19 shows the matrix with key design characteristics and success criteria for different types of technology and media products.

**Table 17.** *Success criteria matrix for technology and media products*

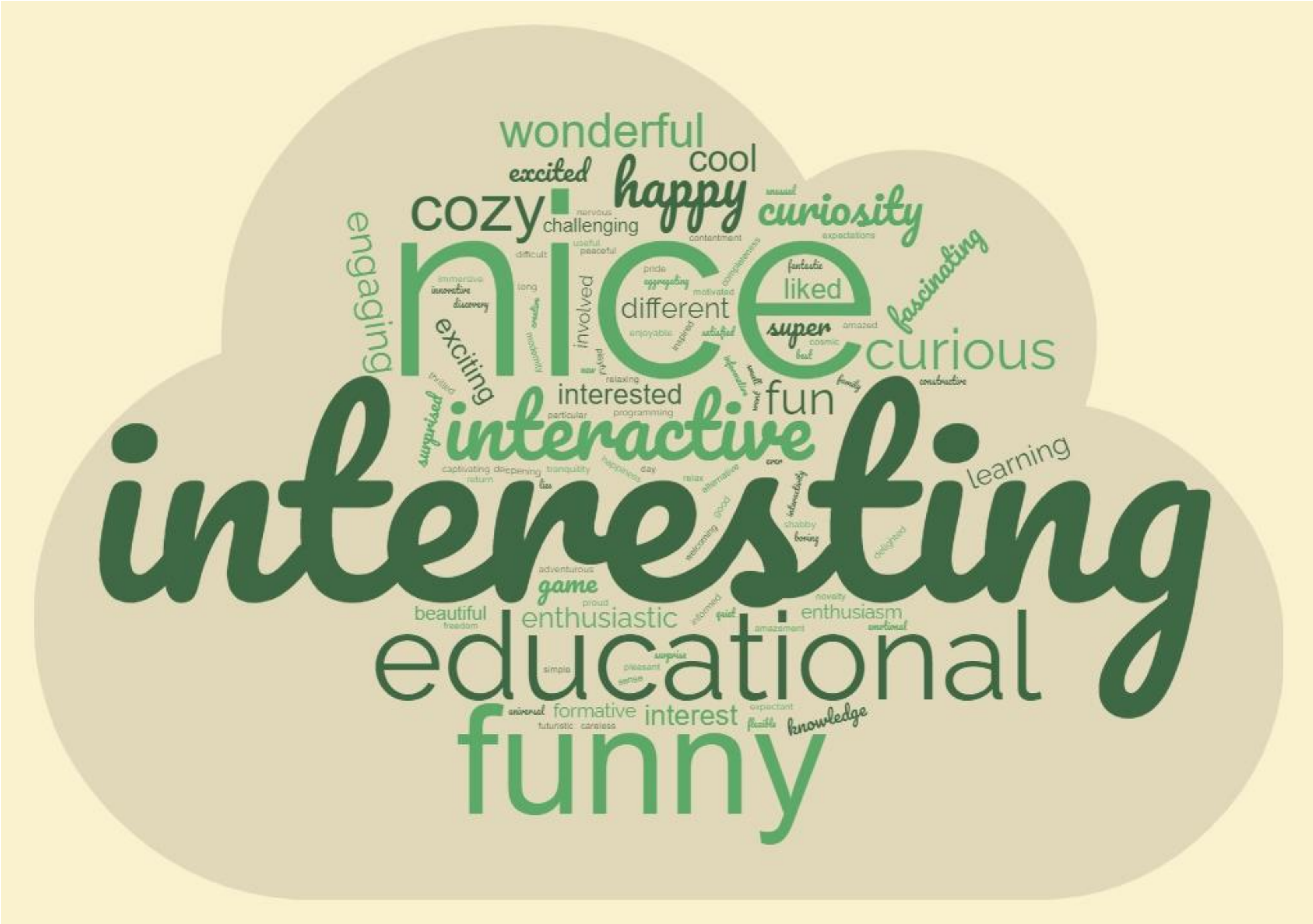
| | Accessible/ easy to use | Connection to real life | Encouraging curiosity/ questioning/ inquiry | Visually attractive (design) | Manageable and engaging way of presenting information | Interaction with the audience/ active engagement |
|---|---|---|---|---|---|---|
| website with various activities | | shows how presented scientific | stimulates curios attitude towards | visually attractive design and materials | less relevant or n/a | n/a |

<table>
<tr><td>online exhibition</td><td rowspan="3">is easy to use and accessible via different devices</td><td rowspan="5">phenomenon and/or technology is connected to and used in everyday situations</td><td rowspan="5">various scientific phenomena and information</td><td rowspan="5"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>digital scenario-based activity</td></tr>
<tr><td>radio and tv programmes, podcasts, channels in social media any</td><td rowspan="3">presents information in a narrated and engaging way, with a clear connection to real-life stories</td><td>provides interaction with audience</td></tr>
<tr><td>printed offline products</td><td rowspan="2">n/a</td><td>n/a</td></tr>
<tr><td>dissemination events</td><td>less relevant or n/a</td></tr>
</table>

## *5.4 Participants' perspective*

In addition to analysing the results of the interviews with the participants and visitors of iSTEM activities, we also wanted to get insight in how participants see and what they value in iSTEM learning activities. The interviews were designed to be not very obtrusive, which meant that only a limited amount of information could be collected (see Appendix V for the interview questions). Among the questions, there was a request to describe the activity they had just experienced by three adjectives. Figure 7 shows a word cloud made from the descriptions given by participants, which presents their perspective on iSTEM activities. The word cloud shows that participants valued not only interest and entertainment elements of the activities, but also their educational and interactive nature.

**Figure 7.** *Participants' view on iSTEM activities*



# 6 Conclusion

This document presented the process and the results of the WP2 team work on identifying key characteristics and success criteria for the design of different iSTEM learning activities. Starting with the ways to collect data, participants and procedures of this process, and the approaches to analyse the data, which are described in Chapter 2. Using pre-defined interview questions, 219 stakeholders from different countries and representing three groups (i.e., activity providers, school teachers, and visitors/participants of iSTEM activities) were interviewed. Their answers were used to identify activity types and their key design characteristics.

The document proceeded by presenting activity types identified for each learning context – outreach programmes, designed environments, and technology and media products (Chapter 3). Five activity types were identified for outreach programmes, three activity types were described for designed environments, and six activity types were presented for technology and media products. The work was based on the aggregation and grouping of the interview answers, as well as on checking existing repositories covering iSTEM learning activities in Europe.

Based on the collected data and literature review, key design characteristics for each context were presented in Chapter 4. Design characteristics suggested by activity providers were first grouped to provide a concise list with no overlap, then checked for support in research literature, and finally, compared to the list of characteristics mentioned by teachers and participants. If characteristics were not suggested by activity providers but found in literature and mentioned by other stakeholders, they were added to the list. During this work, several important results were obtained. First, the design characteristics were formulated for each context as activities within one context shared most of the characteristics. Second, two general characteristics that can be seen as pre-requisites for any iSTEM learning activity were found: providing scientifically correct information and being interesting for participants. Third, the number of identified design characteristics differed per context: outreach programme – seven, designed environments – nine, technology and media products – six. Among identified characteristics, some were applicable to all contexts, for example, connection to real life, and encouraging curiosity and inquiry; while others were context-specific, for example, collaboration with peers (outreach programmes), authentic materials (designed environments), and a manageable and engaging way of presenting information (technology and media products).

Finally, success criteria for designing activity types in each context were formulated and presented in Chapter 5 in the form of matrices. In the research stage of the project, these matrices will be extended to show how specific activity types with specific goals can contribute to the development of science proficiency strands. This will be done by investigating selected case studies.

The results of this work will inform the project work in several ways. First, they will help to select case studies for further research (see D 2.3 for more details). Second, they will contribute to the development of assessment schemes for the selected case studies (WP5). Finally, the results will form a base for the development of recommendations and a self-evaluation scheme for activity providers in the Science Booster (WP3), as well as an accreditation scheme for informal learning activities (WP6).

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# 8 List of appendices

| | |
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| Appendix II | Consent form for teachers |
| Appendix III | Interview questions for activity providers |
| Appendix IV | Interview questions for school teachers |
| Appendix V | Interview questions for visitors/ participants |

# Appendix I

# Consent form for activity providers

Consent form

You are invited to take part in the interview conducted by the Surrounded by Science project. The goal of the Surrounded by Science project is to contribute to the exploration of the learning happening outside the science classroom, in other words, when people are involved in informal STEM learning activities, such as visiting a museum, watching a documentary or joining a science club. To get understanding of these learning processes we would like to hear from different stakeholders involved, for example, activity providers, school teachers and visitors of iSTEM activities. That is why we would like to ask you several questions. We would like to hear about your general experience as a science-engagement organisation and about particular activities and programmes you organise.

This interview will take approximately 30 minutes and will be recorded only for the research purposes. Only the project team members conducting the interview will have access to it. After the interview, the data will be processed and anonymised, and the recording will be deleted. The processed data will be used in the project to inform about existing iSTEM learning activities.

At any time during the interview you can decide to stop it without providing a reason. In this case, your data will be deleted and not used in the project.

If you have any questions or remarks about the interview, you can contact [name and email of an interviewer] or [name and email address of the DPO].

I confirm that I have read the consent form and agree to take part in the interview.

Date: Signature:

# Appendix II

# Consent form for teachers

Consent form

You are invited to take part in the interview conducted by the Surrounded by Science project. The goal of the Surrounded by Science project is to contribute to the exploration of the learning happening outside the science classroom, in other words, when people are involved in informal STEM learning activities, such as visiting a museum, watching a documentary or joining a science club. To get understanding of these learning processes we would like to hear from different stakeholders involved, for example, activity providers, school teachers and visitors of iSTEM activities. That is why we would like to ask you several questions. We would like to hear about your general opinion about the formal and informal science education and the way they (can) complement each other.

This interview will take approximately 30 minutes and will be recorded only for the research purposes. Only the project team members conducting the interview will have access to it. After the interview, the data will be processed and anonymised, and the recording will be deleted. The processed data will be used in the project to inform about existing attitudes to and values of iSTEM learning activities.

At any time during the interview you can decide to stop it without providing a reason. In this case, your data will be deleted and not used in the project.

If you have any questions or remarks about the interview, you can contact [name and email of an interviewer] or [name and email address of the DPO].

I confirm that I have read the consent form and agree to take part in the interview.

Date: Signature:

# Appendix III

# Interview questions for activity providers

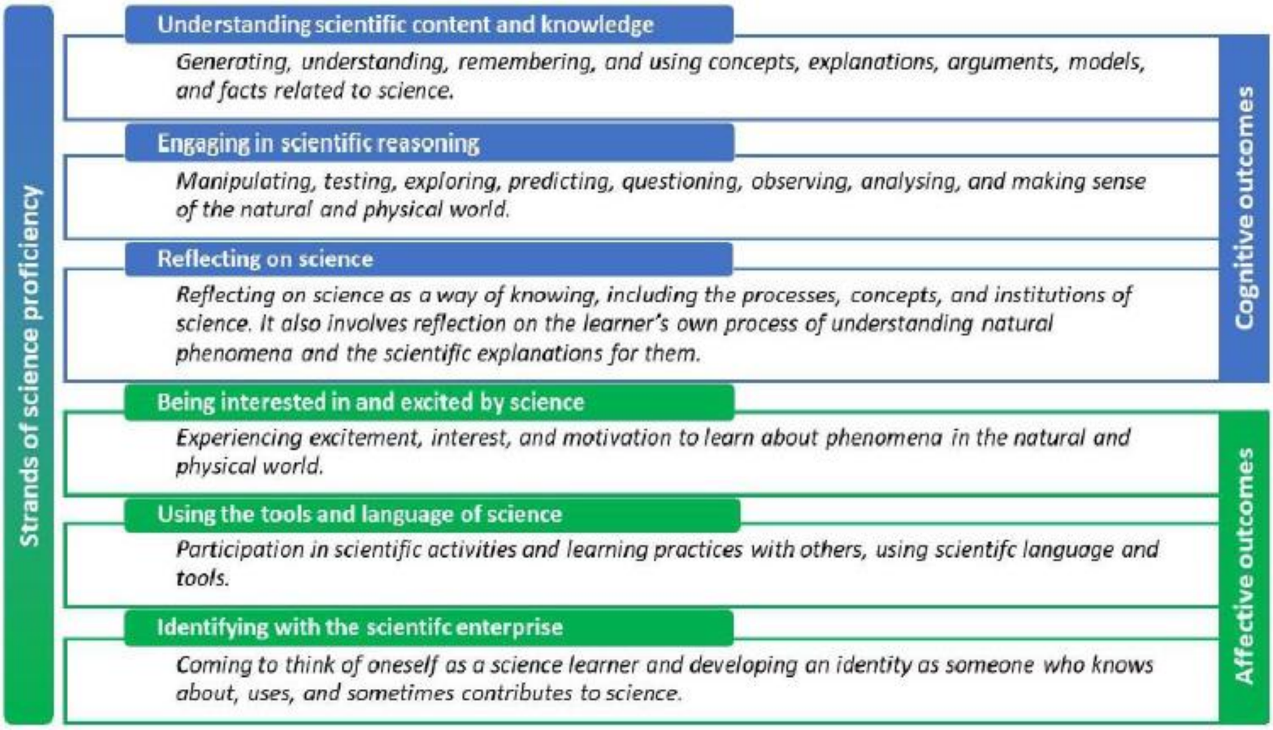
- Organisation goals
  1. As an organisation, what are your goals?
  2. Please rank these strands in terms of the attention they are given in your organisation. (an interveiwee answers in the answer form)
- Activity and its connection to science proficiency (an interviewee can name several):
  3. What is the name and the goal(s) of the activity?
  4. Which areas of STEM does it cover?
  5. What are the target groups?
  6. And what do visitors do?
  7. How much time is the activity intended for?
  8. Based on the indicated goal and visitors' actions, what are the goals of the activity in terms of the SP strand(s)? (see Figure 8)
  9. Please indicate what the contribution of this activity for each SP strand is now (1-5) and what the desired state would be (1-5). Use different colours to distinguish between the current and the desired state. (an interveiwee answers in the answer form)
- Key design features:
  10. What characteristics did you consider important while designing the activity? By design characteristics we mean things like the level of interactivity, control of the experience by the visitor, connection to real life, etc.
  11. Why do you find them important?
- Impact evaluation:
  12. How do you evaluate the effectiveness of the activity? What are the goals and the instruments?
  13. Do you measure any contribution to SP?
  14. Do you want to evaluate other strands of SP? How?
- Place of the activity in a bigger picture:
  15. Does the activity relate to STEM learning in formal settings? If yes, how?
  16. Do you know any other iSTEM learning activities that participants of this activity can take as preparation and/or as follow-up?

**Answer form for interviewees**

2. Please rank these strands in terms of the attention they are given in your organisation.

| **Strand of science proficiency** | **Rank position** |
|---|---|
| Understanding scientific content and knowledge | |
| Engaging in scientific reasoning | |
| Reflecting on science | |
| Being interested in and excited by science | |
| Using the tools and language of science | |
| Identifying with the scientific enterprise | |

**Figure 8.** *Science proficiency model*




9. Choose an activity or program that you feel is an example of one of your organization's "best practices".

Please indicate what the contribution of this activity for each SP strand is now (1-5) and what the desired state would be (1-5). Use different colours to distinguish between the current and the desired state.

If you talk about several activities, indicate possible contribution for all of them.

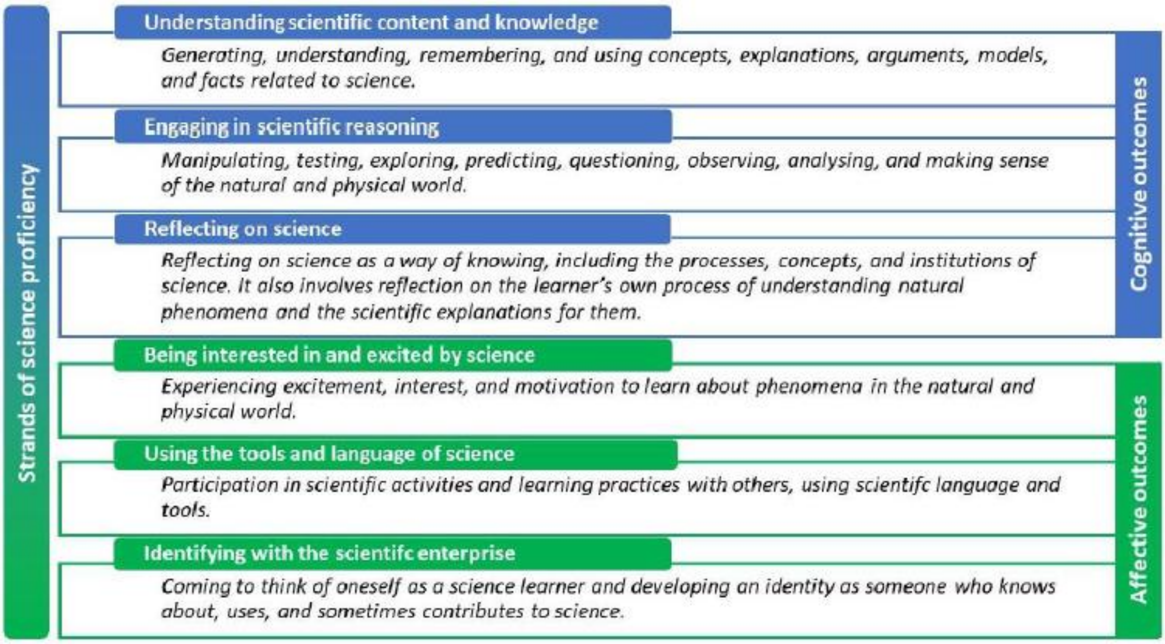
| **Strand** | **1**<br>**No contribution** | **2**<br>**To a very small degree** | **3**<br>**To a moderate degree** | **4**<br>**To a good degree** | **5**<br>**To a very large degree** |
|---|---|---|---|---|---|
| Understanding scientific content and knowledge | | | | | |
| Engaging in scientific reasoning | | | | | |
| Reflecting on science | | | | | |
| Being interested in and excited by science | | | | | |
| Using the tools and language of science | | | | | |
| Identifying with the scientific enterprise | | | | | |

# Appendix IV

# Interview questions for school teachers

1. What is your goal when you teach your subject?
2. Which SP strands do you (aim to) contribute to while teaching your subject? (see Figure 9)
3. Are there any strands that do not fit into the formal education settings?/ What do you want your students to acquire that school cannot give them now (because of time limits, etc.)?
4. What do you see as an added value of iSTEM activities (that you are not engaged in as a teacher)?
5. What kind of iSTEM activities do you find beneficial for your students? Why?

**Figure 9.** *Science proficiency model*



# Appendix V

# Interview questions for visitors/ participants

1. Which [exhibition, activity] did you see/ participate in today?
2. Why did you come here today?
3. What did you like most about this [activity]? Why?
4. What was the least interesting? Why?
5. What did you learn today?
6. Do you think you will carry on studying the topic of the [activity] on your own? If yes, how?
7. What are the three words that describe how you felt during the experience that you had at the [activity]?