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Learning Paths towards Science Proficiency

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Conceptual Design of the Science Chaser app

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Executive Summary

The current deliverable describes the conceptual design of the Digital Toolbox, with a specific focus on the conceptual design of the Science Chaser app. It describes the specification of the tasks and requirements and presents the derived specifications in the form of the conceptual design.

The document provides a general overview of the goals of the Science Chaser and Science Booster, the two main apps of the Digital Toolbox. The document describes how the two apps will be used in different iSTEM contexts, by individual users, science organisations, and researchers. Users can document their science journey using the Science Chaser, science organisations can orchestrate the users' journey by specifying specifics routes or by offering and highlighting activities in the Science Chaser. Researchers can use the Science Chaser to collect data about the iSTEM activities users engage in. The Science Booster is a tool that helps science organisation to align the activities they offer with their intended goals.

The above illustrates that the Digital Toolbox will have different groups of users, and some of these users will also create content for the apps. In the current deliverable, we will introduce the goals of the Science Chaser and the Science Booster and explore the tasks from the perspective of the three user groups through scenarios of usage. Based on this task analysis, a list of requirements is specified. Following these requirements, we present a general description of the two web apps and the data flow. The conceptual design will be tested against use cases.

The future work section provides a time lime of the development of both apps also in relation to the input that we will receive from other work packages.

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1. Introduction

This deliverable describes the conceptual design of the Digital Toolbox of the Surrounded by Science project, with a specific focus on the conceptual design of the Science Chaser app. The conceptual design is part of WP3, Digital Toolbox.

The deliverable will open with a general description of the Digital Toolbox and the two main applications that are part of the toolbox (i.e., the Science Chaser and Science Booster). It also introduces the Digital Toolbox manager that allows project members to manage the content of the Science Chaser and the Science Booster.

In Chapter 3, we present general scenarios for using the Science Chaser in each of the iSTEM contexts that were defined in WP2 (research framework, see also deliverable D2.1). For each of the three iSTEM contexts, a task analysis has been performed from the perspective of a science organisation, a researcher, and a participant/visitor. This resulted in a list of tasks and functionalities that is presented in Chapter 4. This list of functionalities provided input for the conceptual design and the architecture, which are presented in Chapter 5. In Chapter 6, the conceptual design is applied to the use cases from the three different iSTEM contexts that were discussed in Chapter 3. For each of the contexts, we took a concrete example and applied the design. In Chapter 7, we provide a short overview of the future work in WP3, and we provide our conclusions in Chapter 8.

This document is related to deliverable D2.1, which -among others- defines the iSTEM contexts in which the Digital Toolbox will be used, and provides an overview of the research activities in the project. The described Digital Toolbox is related to D4.1, which will describe how the Digital Toolbox will be used in the context of research and D5.1, that will -among others- provide assessment instruments that will be made available through the Science Chaser. Moreover, this deliverable is related to D8.1, which describes the ethical approval procedures in the Surrounded by Science project, and deliverable D8.2, which describes the processing of personal data.

2. The Digital Toolbox

Central in the project is the development of a Digital Toolbox that will expand our understanding of the impact of iSTEM activities on an individual's science proficiency and that will assist science organisations in the process of developing more effective iSTEM activities. To facilitate this, the Digital Toolbox contains two main apps, the Science Chaser and the Science Booster, and a Digital Toolbox manager dedicated to managing the data flow and content of the Science Chaser and the Science Booster.

The Science Chaser will help the project team to better profile the audiences of iSTEM activities and understand their preferences and interests. When individuals use the Science Chaser app during activities that are associated with the project, the Science Chaser will be used to collect specific data about the participants' interaction with this activity, and the impact of the activity on the participants' science proficiency. The Science Chaser will also provide the participants with a tool to document their individual out-of-school science journey by monitoring the iSTEM activities that are performed in the Science Chaser app and by inviting the participant to report the science related activities they engaged in outside the app. The information gathered will provide essential information that will help understand the factors that make science activities effective and how this relates to specific goals and target groups. The collected data will be used to make inferences about the goals, interests, and performance in order to provide appropriate information and challenges.

The Science Chaser will include gamification elements that make it an interactive and fun platform for the participant to report their engagement in iSTEM activities, do activities, and find new information and challenges. For organisations in the iSTEM field, the Science Chaser will serve as a tool to communicate with their visitors or participants. The Science Chaser can be used to provide the participant with additional information and interactive elements like quizzes. The Science Chaser can provide this information before, during, and after the actual visit or interaction with an iSTEM activity. An example of prolonged contact with a participant and user of the app could be informing the user about new activities. In this way, the science organisations can promote repeated visits to their organisation.

The Science Booster will make informal organisations aware of the impact of their activities on different target groups and will provide them with targeted feedback to improve. The Science Booster will build on existing research in the context of iSTEM and research conducted within the project, by defining key characteristics of activities within different iSTEM contexts and providing success criteria for these characteristics. Using these characteristics and criteria as a starting point, the Science Booster will provide automatically generated and targeted advice and suggestions for improvement.

To achieve this, the Science Booster has two functional components: a self-assessment component and an advice component. The self-assessment involves a questionnaire that science organisations must answer about their science activities. Questions concern the goal of the activities, the target group, the content, the pedagogical approach, the design, etc. The self-assessment can make science organisations more aware of the intended goals of their science activities and the expected outcomes on science proficiency and see whether they align or not. Additionally, it can make them more aware of the audience they serve and whether their activities are accessible for all subgroups within the target group. Based on the information provided in the self-assessment component, science organisations receive advice. This advice includes targeted feedback and suggestions for improvement. It is a tailored advice (based on the identified success

criteria) that is adapted to the specific characteristics and objectives of the activity and organisation. The Science Booster will be described only briefly in the current deliverable. The development of the Science Booster is planned for the last year of the project and the exact functionality of the Science Booster will be based on the key characteristics and success criteria that will be defined in the coming year.

The Digital Toolbox manager is an additional tool that is available for project members and organisations. It allows the project management to create and manage accounts for different types of users (participants, project members, and science organisations). Depending on the rights associated with the account, project members can create and edit content in the form of artefacts through the Digital Toolbox manager. An artefact is the smallest element or activity where the Digital Toolbox interacts with the participants. They can also define specific sequences of artefacts that participants can or must use. Moreover, the Digital Toolbox manager facilitates the creation of assessment elements (including questionnaires and knowledge tests) and allows researchers to specify how and when these assessments should be administered. Users (that have the required rights) can also access the data through the Digital Toolbox manager.

3. Scenarios

In this chapter, we will present general scenarios for using the Science Chaser in each of the iSTEM contexts as defined in our project (i.e., Designed Environments, Scientific Outreach Programmes, Technology and Media Products, and the Everyday Life Perspective, see also deliverable D2.1 for more information), as well as the use of the Science Booster. For each iSTEM context, we performed a task analysis aiming to point out in what way the Science Chaser will be used by individual participants, science organisations, and researchers. For the researchers, we will discuss the three different research perspectives that were formulated based on the grain-size continuum of measurements of engagement in science learning, the context-oriented perspective, the person-in-context perspective, and the person-oriented perspective (see also deliverable D2.1). For the Science Booster app, we will present one general scenario. The scenarios and ways in which the apps are used will form the input for the list of tasks and technical requirements for the Digital Toolbox that will be presented in Chapter 4, and a design that is presented in Chapter 5.

3.1. Designed environments

Designed environments are learning environments that are designed by out-of-school organisations and that aim to provide specific information or experiences that are often part of family or leisure related activities. Typically, the engagement with a designed environment is short-term and occasional and having fun is considered an important goal. Contextualized learning and engagement are the main characteristics of the learning activities that belong to this learning context. Examples include visits to exhibitions in museums and science centres, botanical gardens, zoos, planetariums, aquariums, and other thematic parks. In the following sub-paragraphs, we will explore the tasks of the Science Chaser from the perspective of the visitor, the science organisation, and the researcher in the Surrounded by Science project.

3.1.1. The participant and the Science Chaser

Visitors can enter designed environments as an individual, as a family, or as part of a group (like a school class or a group of friends). Before the actual visit, individuals and families who already use the Science Chaser app, might look up information about the designed environment through the app. This might include practical information about the location and opening hours, but can also be specific information, for example about the type of animals in the zoo, or the exhibitions at the museum. Specific information (like a baby elephant that was recently born at the zoo) might even motivate people to visit the zoo. This implies that the Science Chaser should have input and display functions for textual and pictorial information and short video clips. People that have not yet installed the Science Chaser app on a mobile device can be made aware of the app at the entrance and are provided the opportunity to install it and register. This requires a registration functionality that is quick and easy and in line with issues related to ethics and privacy. Upon registration, visitors answer a question about their age range for a first approximation of their entrance level. To stimulate people to register, it should be made clear that using the app provides the visitors with additional opportunities to interact with the environment and provides access to fun science related information and games after the visit. After registering, the visitors can use the app to interact with part of the environment by scanning tags that will provide them with additional content including quizzes and minigames. These experiences are aimed at enhancing interaction with the environment and increasing engagement and fun. This implies that we should have the possibility to scan tags or QR codes and create and display quizzes and minigames. After the exhibition, visitors that continue to use the Science Chaser can receive content related updates, links to related materials (like a documentary related to the animals or exhibitions they

visited) provided by the organisation. Moreover, they can be updated about new activities provided by the organisation. This task is related to the already mentioned functionality to create and display information.

For individuals who enter the environment as part of a larger and organized group (for example in the context of a school visit or as an activity during a camp, the registration and preparation might take place in the context of the group. For instance, a group of students already registered during class, and participated in preparatory activities. Not all visitors might be able to access the app through a personal device; they might work on devices that are made available by the organisation or the party that organizes the visit. Creation of a personal (anonymized) logging facility allows for logging the activity in their personal science journey and creates the possibility to receive dedicated updates and information after the visit.

3.1.2. The science organisation and the Science Chaser

Organisations can use the Science Chaser to prepare visitors for the actual visit, increase interaction with the designed environment during the visit and stay in contact with the visitors after the visit. Before the visit, the Science Chaser can be used to prepare the visitor by providing both practical and content related information. On the practical side, the app can, for example, include the time schedule of live demonstrations; on the content related side, some inviting facts or statements can be shared that trigger curiosity. This task refers to the aforementioned functionality to create and present information. Therefore, the app should be advertised at the website (for example at the place where people book their online tickets). For visitors that do not have the app installed before the visit, the installation of the app should be promoted at the entrance, so that the app can be used during the visit to promote engagement and interaction. A quick and easy registration policy (in line with ethics and privacy rules and regulations) is also important for the organisation. Organisations might want to increase interaction and engagement by allowing the participant to take part in add-on activities that enrich their visit. Examples of these add-on activities are quizzes related to the material or questions that can be answered in the app during the visit in order to obtain points. The Science Chaser can also be used to share materials that cannot be easily observed or interacted with during the visit, or to provide additional explanations or depth to the environment by sharing material through the app. This material can be adjusted to the visitor. If the material is available in various levels of depth, complexity, or language, the information from the profile (language preferences and age for example) will be used to present the appropriate information. Of course, if the participant is interested or has a lot of prior knowledge, information with higher levels of depth and/or complexity can be selected. After the visit, the organisation can stay in contact with the visitor by providing them with updates and additional information. A first step might be proving them with information related to an activity they participated in (for instance feedback on a quiz they participated in during their visit). The necessary functionalities to create opportunities for interaction include scanning options for a tag or QR code, tools to create and present quizzes and questions, as well as pictorial and textual information. If the organisation has material related to an activity available in multiple languages or at multiple levels of complexity, it should be possible to present the participant with the most relevant and appropriate material.

3.1.3. The researcher and the Science Chaser

Researchers are interested in the way visitors/participants interact with the environment and to what extent science proficiency is developed. Not all information about the interest of the participants and their interaction with the designed environment is obtained through the Science Chaser. Simple observations on-site can also inform the researchers about the places of interest.

For the person-in-context oriented measures, the researchers are interested in the type of activities visitors are interested in. This can partly be tracked by the app, for example when interacting with an activity, participants can scan a tag, which will allow them to interact with information or a quiz. This implies that the Science Chaser should not only be able to select an artefact by scanning a code, but that information about the artefacts that are selected by scanning should be stored for later access and analysis. To get additional information, the questionnaire and test functionality can be used to collect information through short self-reports and questionnaires. For research purposes, this information should be stored for later access and analysis.

To get a more detailed understanding of the effects that iSTEM activities have on individual visitors, a more in-depth study will be performed with a group of selected participants. For this purpose, more elaborated tests and questionnaires will be administered before and after interaction with the activity. Administration of these test and questionnaires can proceed through the Science Chaser web-application, for longer test and questionnaires this application can also be used on a regular PC, laptop, or tablet. During the activity, individuals are either followed through observation or by technology through the codes or tags they scan. The collected information should be stored for later access and analysis. Data flow and storage will be described in more detail in Chapter 5.

3.2. Outreach programmes

Scientific outreach programmes refer to coherent programmes, that are designed and organized by out-of-school organisations and include a curriculum that is related to the main activities of the organisation. The activities in this category are typically focused on making information that is available at the organisation accessible and understandable for the wider public. Examples of learning activities in this category include after school programmes, summer courses, research facilities outreach programmes, citizens science projects, focussed programmes in museums and science centres, making and tinkering programmes, field trips, contests, etc.

3.2.1. The participant and the Science Chaser

Participants will enter the outreach activity as an individual or a group. Similar to visiting a designed activity, participants might have already installed and registered in the Science Chaser and used it to orient on the activity by reading the available information. Similar to the context of the designed environments, this implies that the Science Chaser should have input and display functions for textual and pictorial information and short video clips and that the registration process should be quick and easy.

Depending on the duration of the outreach programme, the participants of the Science Chaser will either report their activities in a dedicated journal format for activities that require several sessions and/or include activities that participants perform on their own. For shorter activities, the general test and questionnaire tools, that were already introduced in the section on designed environments will suffice. A dedicated self-report tool refers to a kind of questionnaire in the form of a diary in which students can complete self-reports and questionnaires related to the different organized sessions but can also include activities that they performed on their own in the context of the outreach program. This requires that for each organized session, the appropriate self-reports and questionnaires are presented and that there is room to provide data about activities performed at the visitor's own initiative. Gamification elements are available for the participant, to stimulate the completion of questionnaires and self-reports. Functionalities should include the display of information related to the activity (either textual, pictorial, or through a video), allowing

for free text input by the participant, and functionalities related to the completion of scales (for the self-reports) and test.

After participation in the outreach activity, the Science Chaser can be used to receive content related updates and links to related materials (like a documentary related to the topic of the outreach programme) provided by the organisation. Moreover, they can be updated about new activities provided by the organisation. This functionality is related to the already mentioned functionality to create and display information.

3.2.2. The science organisation and the Science Chaser

For the science organisation, the Science Chaser offers the possibility to stay in contact with the participants and provide opportunities for reporting activities. Like the functionalities needed in the designed environment, providers of outreach programmes will need functionalities to create opportunities for interaction. These functionalities include scanning options for a tag or QR code, tools to create and present quizzes and questions, as well as pictorial and textual information. In addition to this, the activities in an outreach programme might require the participants to report findings or observations in a field notebook. This notebook can take on the form of a questionnaire that provides options for selection of question sets, open and multiple-choice questions and can have different entries over the duration of the project. If the organisation has material related to an activity available in multiple languages or at multiple levels of complexity, it should be possible to present the participant with the most relevant and appropriate material. The starting point for providing information is the information provided by the participant in the user profile. Options for uploading and sorting or tagging information (for example based on the level of complexity) should be possible for the organisation.

After completion of the outreach activity, the organisation can stay in contact with the participant through the Science Chaser. This can be done, for instance, by sharing updates related to the content of the activity, information, or quizzes. Easy uploading and editing functions facilitate this process.

Science organisations will receive an overview of participant activities that the Science Chaser was involved in. This, for instance, could be the scores on the self-reports or interaction times. This provides the science organisation with a first impression of the visitors' interaction and appreciation of the activity. Therefore, interaction logged by the system needs to be translated into a general visualisation.

3.2.3. The researcher and the Science Chaser

The context-oriented approach focusses on the characteristics of the context and how the visitors or participants related to them. In the context of the outreach programmes, we are interested in the activities that participants exhibit (prolonged) attention to. Depending on the exact characteristics of the activity, this can involve tracking the numbers of participants that start the programme, continue, and finish the programme. Also based on the number of interactions with specific activities (for instance reporting that you have made an observation or engaged in an experiment that was part of the programme), we can see what type of activities are attractive for the participants. This information can be tracked by the Science Chaser. For on-site science programmes, observations can be used and there is no direct need to use the Science Chaser. However, it is possible to use a tag or QR scanning function to indicate that you participate in an activity. For programmes that require activities that participants execute at their own initiative, the dedicated self-report tool allows us to derive this kind of information.

The person-in-context oriented perspective allows the researcher to get a deeper understanding into the actual interaction of the visitor with the programme and the activities within the

programme. Based on the reported or traced activities (see the context-oriented approach) visitors will receive a small set of questions that are more focussed and related to their actual experiences. For the context-oriented as well as the person-in-context oriented perspective, the questionnaire functionalities that have been described before will suffice.

More elaborated and detailed questions related to the six strands of science proficiency will be asked in the person-oriented perspective. Selected activities will be paired with a group of visitors that matches the intended audience of the activities. Administration can proceed through a regular PC, laptop, or tablet. This is often more convenient for longer tests and questionnaires. To make sure that the behaviour and actions during the outreach programme can be related to the test results of the participants, one login should be created that is used for the pre-test, activity, and post-test phase. During the activity, individuals are either followed through observation or by technology through the codes or tags they scan. The collected information should be stored for later access and analysis.

3.3. Media products

3.3.1. The participant and the Science Chaser

In the designed environments and the outreach programmes, visitors/participants can be made aware of the Science Chaser. They can install the app on their personal device or have it installed on the device of their parents or guardians. Users of media products can report their interactions with media products in the Science Chaser app. For the participant, there is an option to report on the iSTEM related activities they engaged in. These activities can be reported, and a tag can be added to categorize the activity or product. When applicable, a link to the product (for example an amazon link to a book, or a YouTube link) can be added, along with a small description. The app provides the participant with content that relates to their interest/previous activities and contains gamification features through which the participant can earn game credits. These media products will be provided by the science organisations. Visitors can select these activities and interact with them. Functionalities that are needed to support the above-mentioned processes include a questionnaire to report the use of multimedia products. Since interacting with the media products is part of the everyday life perspective, reporting will take place in the same reporting functionality.

3.3.2. The science organisation and the Science Chaser

Organisations can suggest media activities that can be included in the Science Chaser. Examples of these are videoclips, links to websites, articles, simulations, or games. These activities can either be materials that are created by the project, the organisation, or by related parties (always in such a way that copyrights are respected). Materials can be used stand-alone by the visitors but might also be related to a specific outreach programme or designed environment. The institution should be able to provide tags that, for instance, indicate the target group, the iSTEM field, and the type of media product. The organisation therefore needs the functionality to create the product (for instance upload the video or the game), describe it, and provide the appropriate tags.

To provide organisations with information about the usage of the media products they provide, a kind of dashboard or overview functionality should be made available. This overview includes data about the actual activities that participants selected and the duration of the interaction. If self-reports or questionnaires were administered in the context of the activities provided by the organisation, they can request a summary of the results. This provides them with a first impression of the visitors' interaction and appreciation of the activity. Therefore, interaction logged by the system needs to be translated into a general visualisation. Functionalities that are needed include

logging of information, and functionalities related to the creation of a visual summary based on the log information.

3.3.3. The researcher and the Science Chaser

Researchers are interested in the media products and activities the participant interacts with. This implies that researchers must be able to create self-report questionnaires that will be available in the Science Chaser, where the participants can add their media related activities. The tool should collect data about the activities that each participant performs within the app, the self-reports, and the activities that participants report on a voluntary basis.

For the person-oriented perspective, the researchers are interested in the way certain media products impact the six strands of science proficiency. Participants will interact with a selected product and complete more elaborated questionnaires and tests. Like discussed earlier, administration can take place via a PC, laptop, or tablet. This is often more convenient for longer tests and questionnaires. To make sure that the behaviour and actions can be related to the test results of the participants, one login should be created that is used for the pre-test, activity, and post-test phase. During the activity, individuals are either followed through observation or by technology through the codes or tags they scan. The collected information should be stored for later access and analysis.

3.4. Everyday life perspective

The previous three contexts take activities that the participants engage in as a starting point of describing usage of the Science Chaser. The current scenario takes the individual participant as a starting point. The everyday life perspective focusses on the way individuals, as part of their everyday life, engage in iSTEM related activities that contribute to their science proficiency.

3.4.1. The participant and the Science Chaser

In all three previous contexts, visitors/participants can be made aware of the Science Chaser. For instance, through an link on a webpage, when they visit a museum or participate in a scientific outreach programme. The visitors can install the app on their personal device or have it installed on the device of their parents or guardians. The app provides the participant with content that is related to their interest/previous activities and contains gamification features through which the participant can earn game credits. For instance, participants could participate in a small quiz or watch an informative movie. Moreover, participants are asked to report their science related activities on a regular basis. For instance, if a participant watches a documentary and performs a kitchen chemistry experiment, this can be reported in the Science Chaser app. Reporting can either be on the own initiative of the participant (reporting it in a kind of diary) or upon request (by completing a short self-report questionnaire). Gamification elements will be implemented to stimulate participants to interact with the activities and complete self-reports. Upon completion of an activity or self-report, the app will present or link to additional information in the Science Chaser and will provide the participant with extra game credits.

3.4.2. The science organisation and the Science Chaser

Organisations can add activities in the Science Chaser app. For instance, links to websites, video material, and on- and offline activities. The activities and materials can be selected by the users of the system. To upload and manage content and artefacts (like materials, suggestions, and questionnaires), an editor should be available. Similar to the media products, the activities and materials that are uploaded by the organisations can be used as a stand-alone activity but might also be related to a specific outreach programme or designed environment. The organisation

therefore needs the functionality to create and upload the artefact (for instance the video or the questionnaire), describe it, and provide the appropriate tags.

Science organisations should be able to get an overview of the actual usage of the activities that they made available in the Science Chaser. This overview includes data about the actual activities that participants selected and the duration of the interaction. If self-reports or questionnaires were administered in the context of the activities provided by the organisation, they can request a summary of the results. This provides them with a first impression of the visitors' interaction and appreciation of the activity. Therefore, interaction logged by the system needs to be translated into a general visualisation. Functionalities that are needed include logging of information and functionalities related to the creation of a visual summary based on the log information.

3.4.3. The researcher and the Science Chaser

Researchers are interested in the science journey of the participants. The science journey consists of activities that are available in the app (like a minigame or quiz), but it also consists of the self-reported activities. This implies that researchers must be able to create self-report questionnaires that will be available in the Science Chaser and need anonymized data about the activities that each participant performs in the app, the self-reports that are completed, as well as the activities that participants report on a voluntary basis.

3.5. The Science Booster

The Science Booster is intended to help science organisations to align the activities they offer with their intended goals. This is done through a self-assessment and advice tool. The advice is based on the research conducted within the previous phases of the project: for instance through interviews conducted with stakeholders, data collected during participants' interaction with iSTEM activities, and literature studies. Subsequently, a set of success criteria will be formulated for each type of iSTEM activities that is identified in our inventory (which is part of WP2). These criteria cover different design features: instructional, pedagogical, etc. and are inserted in the app.

3.5.1. Self-assessment in the Science Booster

The self-assessment part allows the science organisations to check how the goals, that they would like to reach, align with the activities they currently provide. To do so, organisations first will need to provide information about the activity including the intended goal(s), the target group, and the key characteristics of the activity. Second, they will be asked to answer evaluative questions concerning the design features of the activity. These questions will include information about the specific ways that the activity provider uses to engage the audience. For example, in a designed environment, questions can cover ways like a presence of a designated route through the exhibition, interactive exhibits, a possibility to adjust the complexity level, etc. The questions will be multiple-choice ones to allow a quick and automated analysis of the inserted data.

3.5.2. Advice in the Science Booster

In the advice part, the organisations will be given some practical recommendations regarding the alignment of their target audience, intended goals and the actual iSTEM activity. These recommendations can be done at various levels, from more general and strategic (e.g., try to include multimedia products in the exhibition) to more specific and tactical (e.g., if visitors are asked some questions during a designated route, they should also be provided with answers to these questions).

4. Tasks and functionalities

In Chapter 3, we sketched how the Digital Toolbox could be used in different contexts by describing general scenarios for use within different contexts, by participants, science organisations, and researchers. In each of the scenarios, different tasks and functionalities of the Science Chaser and the Science Booster were identified. In this chapter, we will provide an overview of the tasks and requirements.

4.1. The Science Chaser

4.1.1. List of functionalities for participants

Each user of the Science Chaser has a personal account. Through this account, the participant can interact with the information that is provided by the science organisation and complete assessments provided by the research team. To create an account and interact with the materials and activities, the following functionalities are needed:

- Download point for the Science Chaser
- Registration procedure
- Providing basic characteristics, such as age category data and preferred language (for customisation).

The Science Chaser can be used to report activities that a participant performs in the context of a designed environment or an outreach programme. This requires the following functionalities:

- Selection menu where participants can select the science organisation
- Selection of artefact. The artefact is seen as the smallest element the participant can interact with. This could be a part of a designed environment, for example sliding down friction slides in the force zone of the London Science Museum, or part of an activity like designing a stable tower as part of an outreach programme on earthquakes.
- Functionality that facilitates participants to interact with a selection of artefacts (related to a specific domain or topic) that is selected by a science organisation
- Scanning functionality (for example QR or barcode) that allows participants to select the artefact they want to interact with
- Game and questionnaire functionalities
- Functionalities that provide artefacts, games, and questionnaires upon a specific trigger, for instance after entering an organisation or upon completion of an activity
- Functionality that provides the participant with points upon finishing an activity, game, or questionnaire, and that updates the gamification part of the Science Chaser.

The Science Chaser should also allow participants to report on the iSTEM activities they engage in by themselves. This relates to iSTEM activities in and outside the Science Chaser.

For activities inside the Science Chaser, this requires the following functionalities:

- Browsing/searching functionality in the list of available artefacts
- Upon interaction with the artefact, the artefact should be added to the profile of the participant.

For self-chosen activities, this requires the following functionalities:

- Entering iSTEM activities
- Tagging function for iSTEM activities
- Option to propose activities, by submitting them through the Science Chaser and ask for approval. The science organisations will decide if activities can be approved.

4.1.2. List of functionalities for science organisations

Science organisations use the Science Chaser to present their activities and interact with the user. In this context, the organisations create, enter, and manage artefacts, games, and questionnaires related to their organisation. Part of the management includes the approval of content that is shared by participants. This requires the following functionalities:

- Functionalities related to creation and editing of an artefact, game, or questionnaire
    - including uploading facilities
    - editing facilities
    - input fields for text descriptions and metadata
- Functionalities related to the suggestion of an artefact
- Functionalities related to the approval of an artefact
- Visualizing or summarizing information related to the way participants interacted with an artefact (for example the number of participants that interacted with the artefact).

4.1.3. List of functionalities needed for research

Researchers are interested in the participants' interaction with artefacts through the Science Chaser in and outside science organisations. For this purpose, the following functionalities are needed:

- Functionality for the creation of longer and shorter questionnaires and tests related to the artefacts
- The possibility to attach a questionnaire or test to a specific artefact
- Tracking of the artefacts with which a specific group of participants interacted
- Downloading data for a specific set of participants (for example visitors of a certain exhibit or people within a specific age range) in an accessible format.

4.2. The Science Booster

Organisations can use the Science Booster to receive advice on the design of their iSTEM activities. The Science Chaser provides a self-assessment tool that collects information about the goals of the activity, the target group, and the characteristics of the activity. The advice provides insights in the alignment of the activity and the intended goals and provides advice on how this can be improved.

For this purpose, the following functionalities are needed:

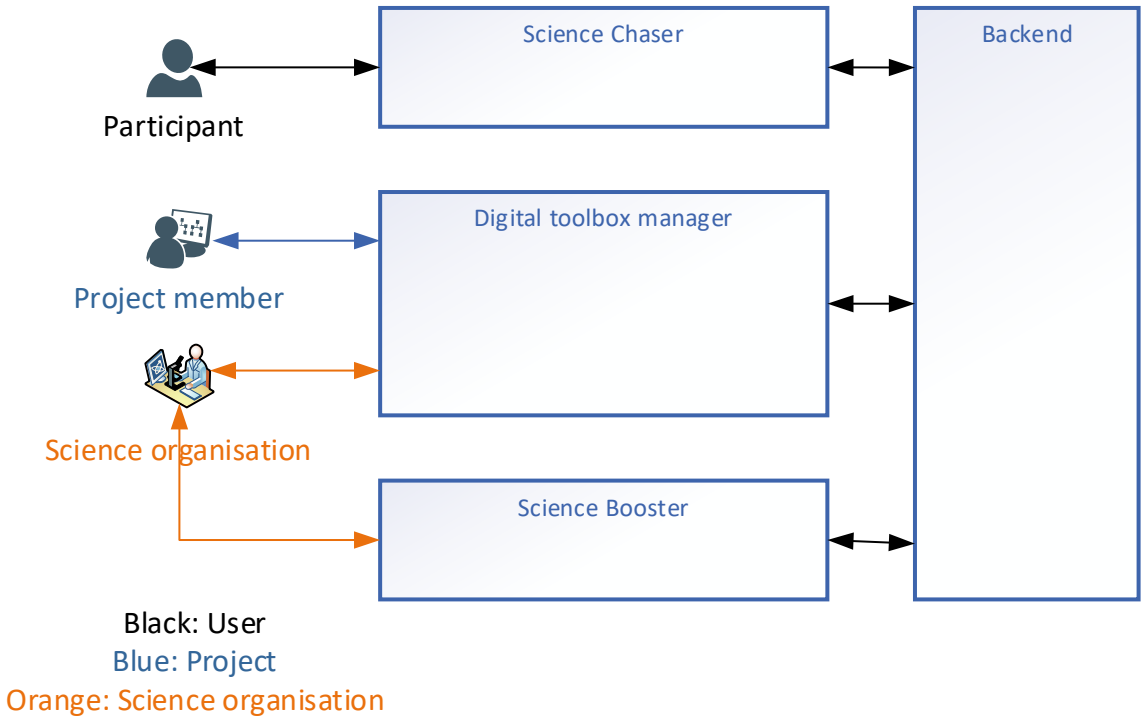
- Login functionality for the science organisation
- A self-assessment questionnaire
- The possibility to link the answers to success criteria
- Selection mechanism for providing advice.

5. Conceptual design and architecture

5.1. Development of the Digital Toolbox

As described earlier, the Digital Toolbox consists of two applications: the Science Chaser and the Science Booster. However, these two applications cannot work without a “place” to store and retrieve data: the backend. The task of the backend is to store all the data needed and produced by the two applications. The data stored in the backend will be managed by the Digital Toolbox manager. An overview of the Digital Toolbox components is shown in Figure 1.

Figure 1. *Overview of the Digital Toolbox*



In this chapter, we will discuss the data flow, data storage, and the conceptual design. Within the project, administrators (operating the Digital Toolbox), project members from different organisations, and participants will work with the Digital Toolbox. The participants can interact with artefacts. These artefacts are basically the smallest units of activity within the Digital Toolbox (for example a booth or stand at a museum) and contain descriptions and interactive research elements (questionnaires etc.). The Digital Toolbox manager will allow the project members to add and modify artefacts and their content elements. In the following paragraphs, the data flow and storage is described in a step by step manner.

5.2. Data flow

In this section, a number of common tasks are described. Each task is described by steps that a project member or participant has to do, followed by a figure showing which parts of the Digital Toolbox and which users are involved.

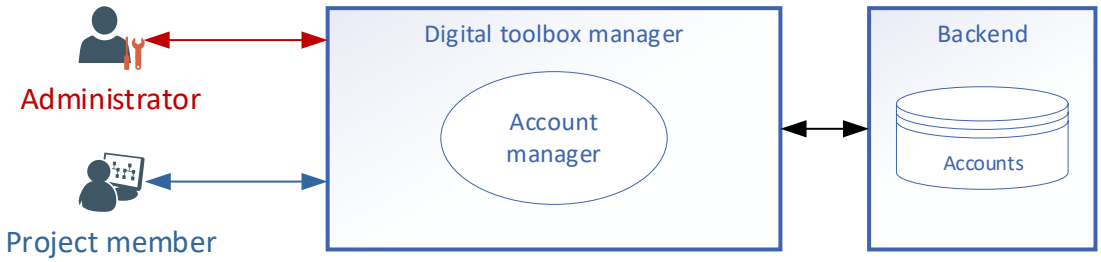
5.2.1. Creating a project member account

Below are the steps for an administrator to create an account for a project member and Figure 2 shows the involved parts of the Digital Toolbox.

1. An administrator logs in to the account manager

2. The administrator creates an account with a name and an email address
3. The administrator assigns the account to a science organisation (if appropriate)
4. The account manager will send a welcome mail to the project member, with a one time link to the Digital Toolbox manager for the account activation
5. The project member goes to the Digital Toolbox manager, using the received link
6. The Digital Toolbox manager shows the consent form with the information about which data will be collected and how they will be processed
7. The project member clicks on agree; disagree means the project member cannot use the Digital Toolbox manager
8. The project member sets the password

Figure 2. *Creating project member account*

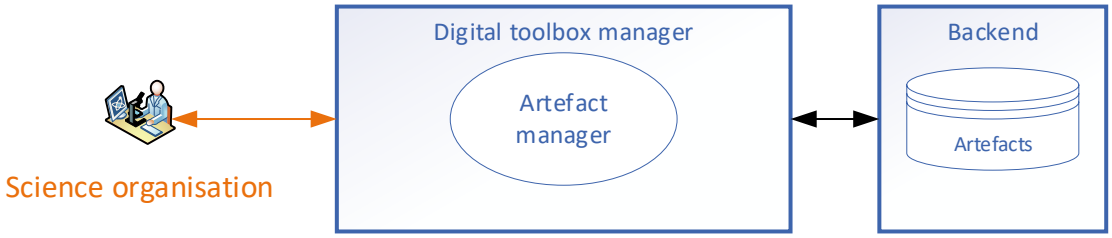


5.2.2. Adding/editing an artefact

Below are the steps for a project member, working for a science organisation, to add or edit an artefact and Figure 3 shows the involved parts of the Digital Toolbox.

1. A project member logs in to the Digital Toolbox manager
2. The project member selects the artefact manager
3. The project member clicks on the button to create a new artefact
4. The project member enters the artefact name, a short description, and the metadata
5. The project member opens the new artefact
6. The project member clicks on the button to create a new content element of the desired type
7. The project member fills the new content element
8. The project member selects the language and a level of the content element
9. The project member closes the content element
10. Go to step 6, until all desired content elements are created and filled

Figure 3. Adding/editing an artefact



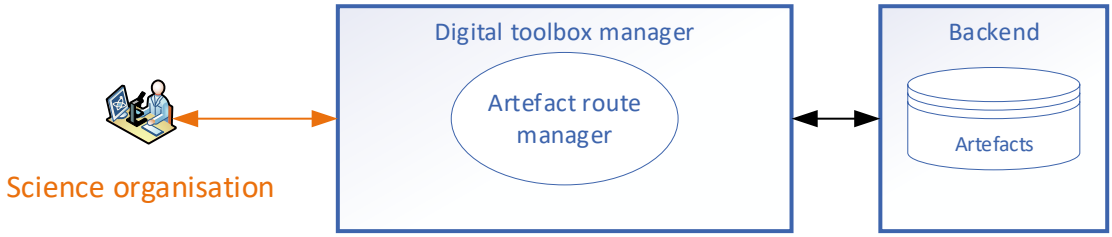
5.2.3. Adding/editing an artefact route

Below are the steps for a project member, working for a science organisation, to add or edit an artefact route and Figure 4 shows the involved parts of the Digital Toolbox.

1. A project member logs in to the Digital Toolbox manager
2. The project member selects the artefact route manager

3. The project member clicks on the button to create a new artefact route
4. The project member enters the artefact route name, a short description and the metadata
5. The project member drags the desired artefacts to the artefact route area

Figure 4. Adding/editing an artefact route



5.2.4. Participant registration

1. Below are the steps for a participant to register with the Science Chaser and A participant goes to the public website of the project
2. The participant downloads/installs the Science Chaser
3. The participant opens the Science Chaser
4. The participant selects the desired language
5. The Science Chaser shows the consent form with the information about which data will be collected and how it will be processed
6. If the participant gives consent, s/he clicks on the agree button. Clicking the disagree button means that the registration ends at this point and the participant cannot use the Science Chaser
7. The Science Chaser shows a registration screen
8. The participant fills in a password that s/he made up him- or herself, the preferred language, age category, level, gender, and country of residence.
9. This information is sent to the backend
10. The backend creates an account with a random user name
11. The backend sends the created username to the Science Chaser
12. The Science Chaser shows the created user name
13. The Science Chaser strongly recommends the participant to remember the user name and password for future login
14. The Science Chaser opens the account property screen

Figure 5 shows the involved parts of the Digital Toolbox.

15. A participant goes to the public website of the project
16. The participant downloads/installs the Science Chaser
17. The participant opens the Science Chaser
18. The participant selects the desired language
19. The Science Chaser shows the consent form with the information about which data will be collected and how it will be processed
20. If the participant gives consent, s/he clicks on the agree button. Clicking the disagree button means that the registration ends at this point and the participant cannot use the Science Chaser
21. The Science Chaser shows a registration screen
22. The participant fills in a password that s/he made up him- or herself, the preferred language, age category, level, gender, and country of residence.
23. This information is sent to the backend
24. The backend creates an account with a random user name
25. The backend sends the created username to the Science Chaser

26. The Science Chaser shows the created user name
27. The Science Chaser strongly recommends the participant to remember the user name and password for future login
28. The Science Chaser opens the account property screen

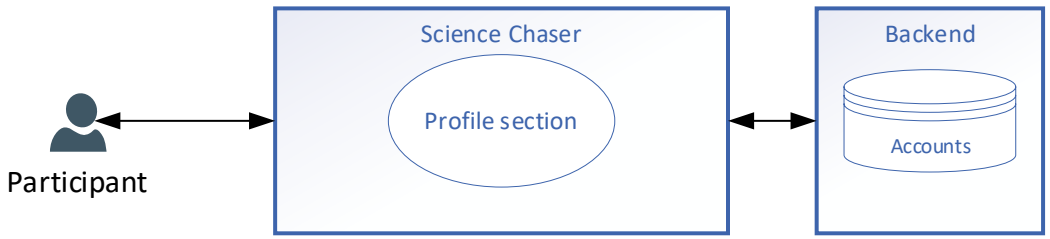
Figure 5. *Participant's account registration*

5.2.5. Participant views/edits their profile

Below are the steps for a participant to view or edit their profile and Figure 6 shows the involved parts of the Digital Toolbox.

1. A participant opens the Science Chaser
2. The participant opens the profile section
3. The Science Chaser shows the profile properties
4. The participant clicks on the edit button
5. The Science Chaser shows the profile properties edit options
6. The participant edits the profile properties
7. The participant clicks on the stop edit button

Figure 6. *Participant views/edits their profile*

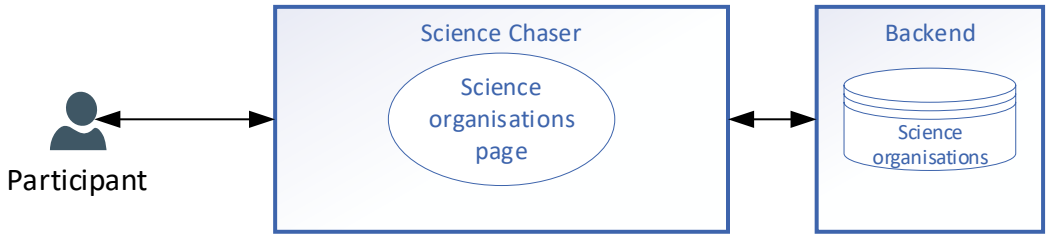


5.2.6. Participant visits a science organisation

Below are the steps for a participant to visit a science organisation in the Science Chaser and Figure 7 shows the involved parts of the Digital Toolbox.

1. A participant arrives at the science organisation
2. The participant installs the Science Chaser and registers, if not yet done
3. The participant opens the Science Chaser
4. The Science Chaser shows a list of science organisations
5. The participant selects the science organisation
6. The Science Chaser shows the science organisation information and a list of its artefacts
7. The participant goes to the desired artefacts and interacts with them
8. The participant selects leave science organisation in the Science Chaser
9. The participant leaves the science organisation

Figure 7. *Participant visits to a science organisation*

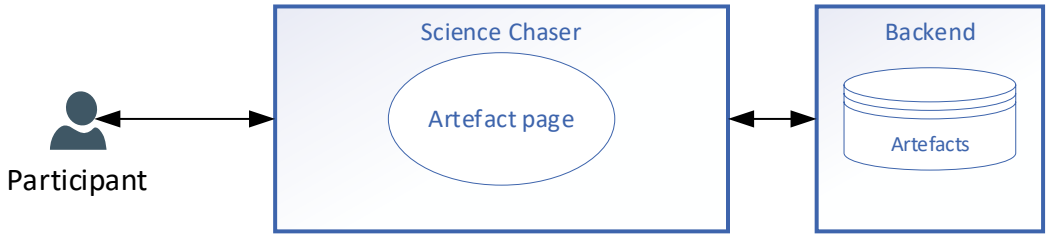


5.2.7. Participant interaction with an artefact

Below are the steps for a participant to interact with an artefact and Figure 8 shows the involved parts of the Digital Toolbox.

1. A participant arrives at an artefact
2. The participant reports the arrival to the Science Chaser
    a. By scanning QR code
    b. Or by selecting the artefact in the Science Chaser
3. The Science Chaser shows the available content elements
4. The participant selects a content element
5. The Science Chaser shows the content element
6. The participant reads or interacts (questionnaire/game) with the content element
7. The participant closes content element
8. The participant goes to step 4 to interacts with more content elements
9. The participant selects leave artefact in the Science Chaser
10. The participant leaves the artefact

Figure 8. *Participant interaction with an artefact*

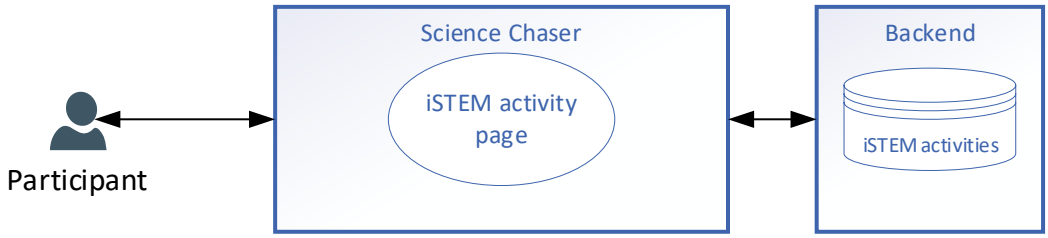


5.2.8. Participant reporting an iSTEM activity

Below are the steps for a participant to report an iSTEM activity, which they did and Figure 9 shows the involved parts of the Digital Toolbox.

1. A participant opens the Science Chaser
2. The participant selects the section “reported iSTEM activities”
3. The participant selects “report new iSTEM activity”
4. The participant enters the title, description and metadata
5. The participant clicks on report iSTEM activity
6. The Science Chaser shows the newly reported iSTEM activity in list of reported iSTEM activities

Figure 9. *Participant reporting an iSTEM activity*

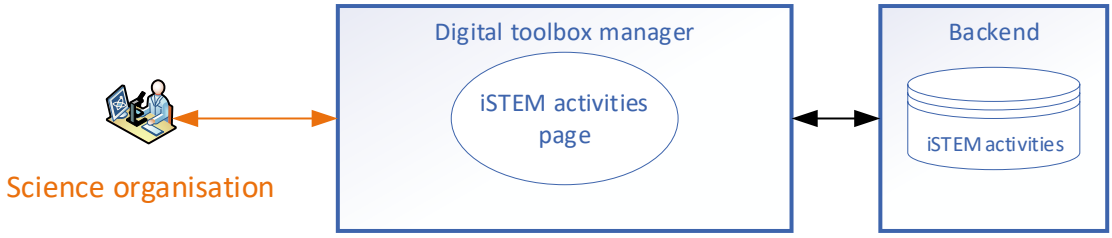


5.2.9. Science organisation publishes a reported iSTEM activity

Below are the steps for a project member, working for a science organisation, to publish a reported iSTEM activity from a participant and Figure 10 shows the involved parts of the Digital Toolbox.

1. A project member opens the Digital Toolbox manager
2. The project member goes to the reported iSTEM activities
3. The project member opens the reported iSTEM activity
4. The project member approves the iSTEM activity for sharing
5. The backend creates a new artefact
6. The backend adds the artefact to the list of interesting artefacts of the science organisation
7. The backend copies the information from the iSTEM activity into the artefact
8. The project member can add additional content elements to the artefact

Figure 10. Science organisation publishes a reported iSTEM activity



5.2.10. Participant browses/searches artefacts

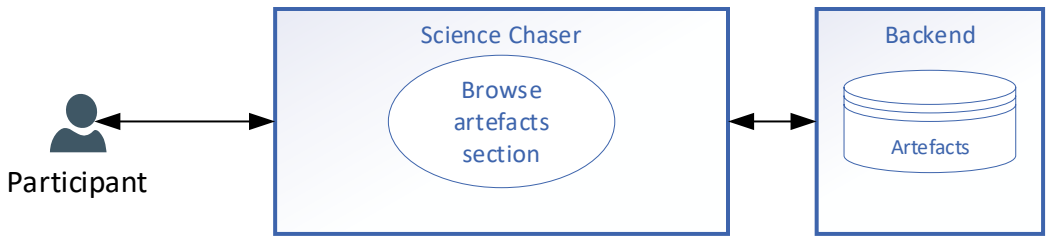
Below are the steps for a participant to browse or search for an artefact and Figure 11 shows the involved parts of the Digital Toolbox.

Steps for a participant to browse or search for an artefact:

1. A participant opens the Science Chaser
2. The participant goes to the browse artefacts section
3. The participant enters the search terms and/or “metadata” (iSTEM subject)
4. The Science Chaser shows the found artefacts

Figure 11Figure 3 shows the project member and the involved parts of the Digital Toolbox.

Figure 11. *Participant browses/searches artefacts*



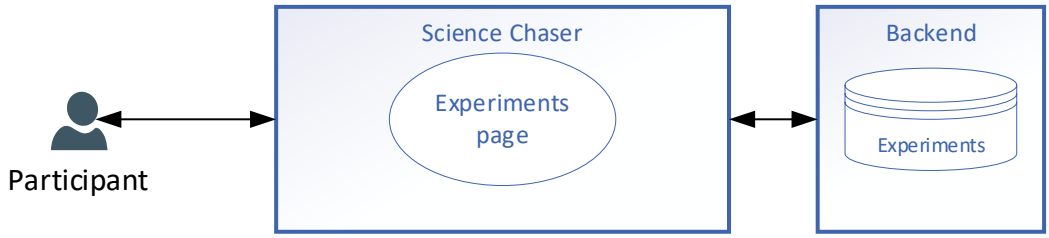
5.2.11. Participant joins an experiment

1. Below are the steps for a participant to join an experiment and A participant opens the Science Chaser
2. There are two ways to join an experiment
    a. Invited by the Science Chaser
        i. The participant selects a science organisation
        ii. The Science Chaser shows the invitation to join an experiment
    b. Invited by a researcher
        i. A researcher checks if consent is given
        ii. The participant enters a code received from the researcher
3. The Science Chaser will show (again) the consent form with the information about which data is collected and how it will be processed
    a. If a participant does not give consent, the participant can continue their visit to the science activity as normal, but does not participate in the experiment. This is the end of step description
    b. If a participant gives consent, the steps continue
4. A flag will be set in the participant's account that s/he is participating in the experiment
5. The Science Chaser will now show additional questionnaires (e.g., pre- and post-tests) to the participant during the visit
6. An experiment flag will be added to the logging of the relevant actions of the participant
7. When the participant selects "leave science organisation", the experiment flag will be removed from the participant's account
8. If the participant forgets to select "leave science organisation", the Science Chaser will remove the experiment flag when the experiment has ended

Figure 12 shows the involved parts of the Digital Toolbox.

9. A participant opens the Science Chaser
10. There are two ways to join an experiment
    a. Invited by the Science Chaser
        i. The participant selects a science organisation
        ii. The Science Chaser shows the invitation to join an experiment
    b. Invited by a researcher
        i. A researcher checks if consent is given
        ii. The participant enters a code received from the researcher
11. The Science Chaser will show (again) the consent form with the information about which data is collected and how it will be processed
    a. If a participant does not give consent, the participant can continue their visit to the science activity as normal, but does not participate in the experiment. This is the end of step description
    b. If a participant gives consent, the steps continue
12. A flag will be set in the participant's account that s/he is participating in the experiment
13. The Science Chaser will now show additional questionnaires (e.g., pre- and post-tests) to the participant during the visit
14. An experiment flag will be added to the logging of the relevant actions of the participant
15. When the participant selects "leave science organisation", the experiment flag will be removed from the participant's account
16. If the participant forgets to select "leave science organisation", the Science Chaser will remove the experiment flag when the experiment has ended

Figure 12. *Participants joining an experiment*



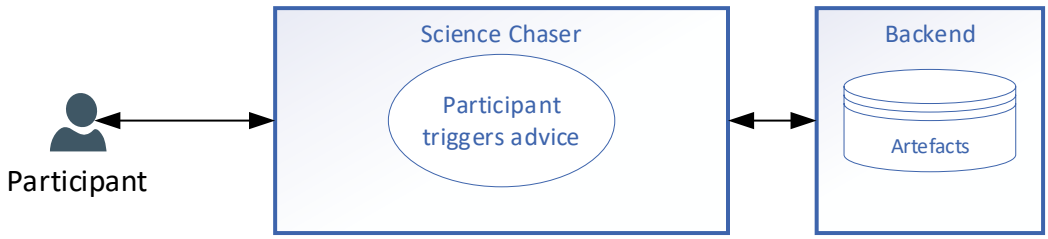
5.2.12. Science Chaser advises artefact

During certain interactions of the participant with the Science Chaser, the Science Chaser can suggest other artefacts which might be interesting for the participant. Examples of such interactions could be: selecting leave a science organisation or entering/reporting an iSTEM activity that has been performed at home.

Below are the steps during the advising of artefacts and Figure 13 shows the involved parts of the Digital Toolbox.

1. An action from a participant triggers the giving advice functionality
2. The Science Chaser asks the backend for the artefact(s) to advise
3. The backend creates a list of artefacts to advise based on
    a. The current or last activity of the participant
    b. All visited activities
    c. The preferences of the participant (as set in the profile)
4. The backend sends the list of advised artefacts to the Science Chaser
5. The Science Chaser shows the list of advised artefacts

Figure 13. *Science Chaser advises artefact*

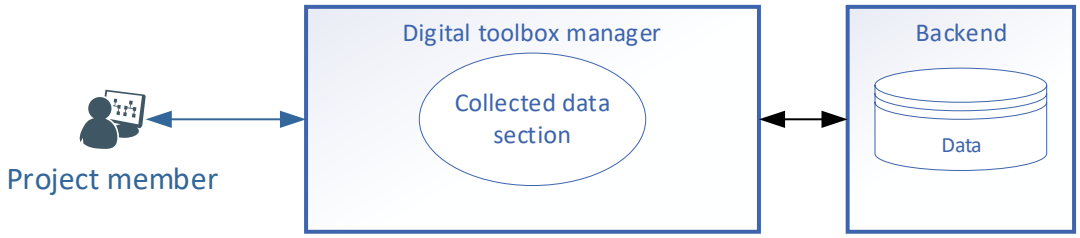


5.2.13. Analysing collected data of participants

Below are the steps for a project member to analyse the collected data of participants and Figure 14 shows the involved parts of the Digital Toolbox.

1. A project member logs into the Digital Toolbox manager
2. The project member goes to the collected data section
3. The project member selects the desired subset (for example, for a specific experiment)
4. The project member downloads the data of the selected subset
5. The project member analyses the data outside the Digital Toolbox

Figure 14. *Analysing collected data of participants*

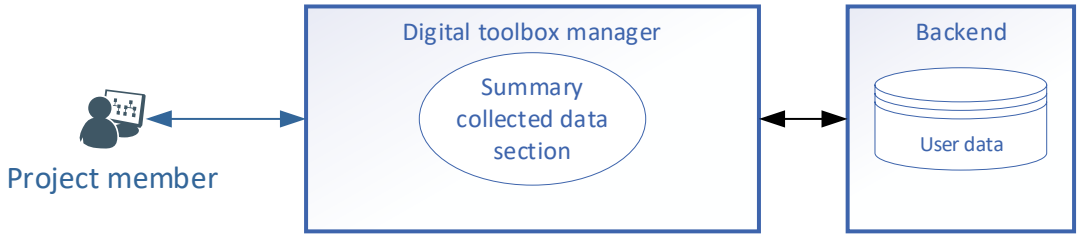


5.2.14. Showing a summary of participants' actions

Below are the steps for a project member to see the summary of the participants actions and Figure 15 shows the involved parts of the Digital Toolbox.

1. A project member logs into the Digital Toolbox manager
2. The project member goes to the section "summary collected data"
3. The project member selects the desired summary
4. Digital Toolbox manager shows selected summary of the data

Figure 15. *Showing a summary of participants' actions*

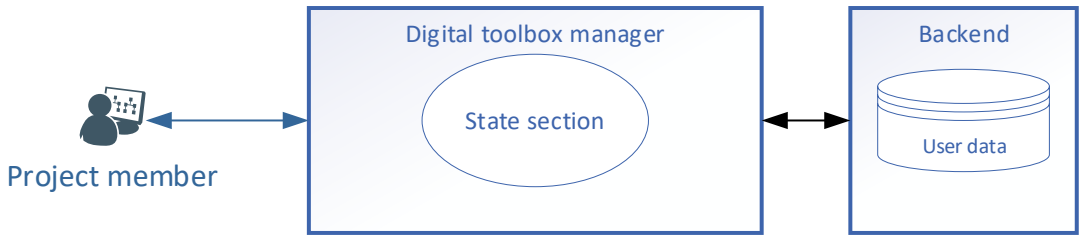


5.2.15. Showing the state of participants

Below are the steps for a project member to see the current state of participants and Figure 16 shows the involved parts of the Digital Toolbox.

1. A project member logs in to the Digital Toolbox manager
2. The project member goes to the state section
3. The project member selects the desired participants (for example, joined a specific experiment)
4. Digital Toolbox manager shows the states of selected participants

Figure 16. *Showing the state of participants*



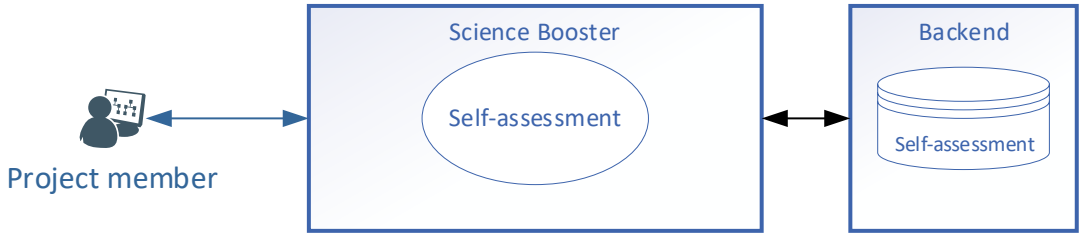
5.2.16. Science Booster showing recommendations based on the self-assessment

Below are the steps for a science organisation project member to see the recommendations of the Science Booster and Figure 17 shows the involved parts of the Digital Toolbox.

1. A project member logs into the Science Booster
2. The project member answers the self-assessment questions

3. The Science Booster shows the recommendations

Figure 17. *Science Booster showing recommendations based on the self-assessment*



5.3. Types of data to be stored

Different kinds of data will be stored and collected in the backend of the Digital Toolbox. In the following sections, each kind of data is described.

5.3.1. Accounts

In order to use the Digital Toolbox you need an account. There are three types of accounts, namely accounts for administrators, project members, and participants.

5.3.1.1. Administrators

An administrator account has all available privileges. It is intended to only be used for administrative tasks, such as managing the accounts of project members and the science organisations in the Digital Toolbox.

5.3.1.2. Project members

A project member account is used to manage the content of the Digital Toolbox. The members of the science organisation will manage the artefacts, while the researchers manage the data collection part.

5.3.1.3. Participants

Each participant has its own account. With this account, a participant can interact with the information of the science organisation and its artefacts.

A participant account has a number of properties. It has a preferred language and optional languages, the Science Chaser itself will use the preferred language and will show only artefacts and their content in the preferred and optional languages.

Each participant account has an age category (e.g., <12, 12-16, >16), a level property (e.g., beginner, intermediate, and advanced), a gender property, a preferred language property, and a country of residence property. Each participant account can have an experiment flag, to indicate that the participant is j participating in an experiment. The properties will be used to select which artefacts alongside their content elements will be visible to the participant.

The research goals can be reached without knowing the identity of the participants. Therefore, no identifiable information of the participants will be collected. A consequence of this is that the project can only communicate with the participants through the Science Chaser. A downside of assigning a random user-name is that it is easy to forget. The project will investigate how a participant can still get access to the Science Chaser if the participant forgets the user-name/password combination, while keeping the participant anonymous.

5.3.2. Science organisations

A science organisation is responsible for entering and managing its artefacts. Project members working for a science organisation, will be members of the science organisation.

Besides being a group of project members, the science organisation also has its own description and owns one or more collections of artefacts. It can offer the participants several routes (sequence of artefacts) to follow. Different artefact routes can be used for different activities.

A science organisation can have a list of interesting artefacts, which are not offered by themselves. These artefacts are related to the activities of the science organisation. For example, these could be interesting articles or YouTube videos related to artefacts which they do offer.

5.3.3. Artefacts

An artefact is the smallest element or activity, where the Digital Toolbox interacts with the participants. It can be a part of an exhibition (such as an ant colony under the ground) or a part of an activity (such as making the scan of a sample in a scanning transmission electron microscope).

An artefact will have a title and an optional short description. The title and short description may be entered in different languages. Some additional subject tags can be added in order to find similar and/or related artefacts. By default, the artefact will get the location of the science organisation. The location can be specified more accurately inside the science organisation locations. This allows the Digital Toolbox to take the distance into account for advising artefacts. Instead of a geographical location, it can also be qualified, like at home, at school or outside.

An artefact is described by one or more content elements like pieces of text, images, videos, and/or experiments. Some content elements may just be a link to the content on the internet. Where possible, the Science Chaser will show the external content in the app. Each content element will have a language and an optional level tag. This allows similar content to be entered in different languages and/or for different age groups. The Science Chaser will show the appropriate elements according to the language and age of the participant.

5.3.4. Interactive/research elements

The project will use different interactive/research elements to collect information from the participants, such as games and questionnaires. This can be used to ask the participant for their opinion, learning progress, or for reflection on what the participant has learned.

The elements can be created by a science organisation or a researcher. The elements can be shown as content elements of an artefact, where it will be tailored to the artefact. An element can also be independent of an artefact and it will be offered to the participant by the Science Chaser on a predefined trigger. Possible triggers are:

- Registration
- Entering/leaving an exhibition of a science organisation
- Starting/ending an activity of a science organisation
- Arriving at/leaving an artefact
- Suggested by a project member

An element can be language specific or language independent. If it is language specific, it will only be shown if the language matches the participant preferences.

The same element may be used for different artefacts or on different triggers. The participants' entry in the element will be stored per instance.

5.3.5. Experiments

The project will run a number of experiments, in which a number of participants will participate. An experiment will have a name, a begin and end date, and an optional description.

5.3.6. Action data

All relevant actions of the participants in the Science Chaser will be logged and stored. These actions can be used for the analyses of the behaviour of the participants.

The relevant interactions of all accounts with the Digital Toolbox will also be logged and stored. This can be helpful for analysing technical problems and possible abuse (by third parties) of the Digital Toolbox.

5.3.7. Participants state data

All relevant actions of the participants are stored in the action store. In general, the current state of a participant can be found here. However, as to prevent intense computing, the latest state will be stored separately. At the design time, the following state storage is expected:

- Questionnaire answers
- Game states
- Scores

The participant can report iSTEM activities which s/he did outside the visits to and activities from science organisations. The reported iSTEM activities will be stored in a separate storage. If possible, useful metadata will be added automatically to make reuse easier.

5.3.8. Science organisation self-assessment answers

The Science Booster needs information from the science organisation before it can give advice to the science organisation. This information will be collected in the form of a self-assessment questionnaire. Based on the answers, advice will be given to the science organisation.

5.3.9. External data

In addition to collecting data through the Science Chaser, data will also be collected by observations of and interviews with the participants. This data is stored and handled outside the Digital Toolbox and is thus outside the scope of this deliverable. However, processed results of this data might be used, together with the answers of the science organisations on the self-assessment, by the Science Booster for giving advice to the science organisation.

5.4. Conceptual design

5.4.1. Backend

In most of the cases, the backend will only respond to external actions (project members managing the content and participants interacting with the Science Chaser). Access to resources will be handled based on roles and ownership of the resource. The following roles are foreseen:

- Administrator
- Researcher
- Science organisation
- Participant

The backend will only be responsible for storing, retrieving, and updating (CRUD operations) the data and keep the data in a valid state. It is not responsible for any UI of the data. The Digital

Toolbox manager will handle the UI of the editing and the Science Chaser will handle the displaying to the user.

All the access to the backend will go through GraphQL. This allows a flexible access to the data, without the need to create separate endpoints for every type of access.

The backend will use the microservice architecture. This allows high decoupled services, which can easily be developed and tested. During the development of the Digital Toolbox, new features can easily be added, through adding new microservices.

5.4.2. Digital Toolbox manager

The Digital Toolbox manager will be a web application. The web UI will be designed for laptop/desktop computers. Mobile devices are less suitable for this, due to their small screen size.

A plugin architecture will be used for the editing of content elements of the artefacts, and reporting of collected data. This will make it easier to add editors for new kinds of content for artefacts and new types of reporting.

The UI of the Digital Toolbox manager will use the English language. The editable content of the Digital Toolbox can be in multiple languages.

5.4.3. Science Chaser

The Science Chaser will be implemented as a progressive web application (PWA, https://en.wikipedia.org/wiki/Progressive_web_application). A PWA can behave like an app on mobile devices (and on laptop and desktops). However, it is still a web application running inside a web browser, which is using a similar UI as a normal mobile application. The whole PWA can be cached on the mobile device, allowing for a fast response and to continue running while the mobile device is offline. Of course, while the device is offline, it can only work with the cached data (just as a real mobile app).

As a PWA is running inside a web browser, it can only do what the web browser allows it to do. If during the usage of the Science Chaser it turns out that the limitations of a PWA are unacceptable, real mobile apps will be created. In this case, the development effort of the PWA is not lost; the web application can just be used inside the mobile app and only the inaccessible mobile device features (from a PWA) will be accessed in the app native way. The way of working greatly reduces the additional effort for creating and maintaining a native app for Android and iOS.

The Science Chaser will always take the lead in communication with the backend. The Science Chaser might not always be running and the mobile device might be offline. If the mobile device is offline, the Science Chaser will continue to work in a limited way, only cached information can be shown. However, participants will always be able to report on iSTEM activities that they have engaged in. The entered data will be cached on the mobile device and sent to the backend when it is online again.

A plugin architecture will be used for displaying content for the artefacts. This will make it easier to add editors for new kinds of content for artefacts.

The Science Chaser itself will be available in the native languages of the science partners in the project. This is independent of the artefact content.

5.4.4. Science Booster

The development of the Science Booster is planned in the last year of the project. The conceptual design will be made then. In that way, we can make use of the experience of designing and implementing the backend, the Digital Toolbox manager and the Science Chaser.

6. Applying the design to the use cases

In the current chapter, the conceptual design presented in Chapter 5 is applied to three concrete use cases from the iSTEM contexts, that were introduced in Chapter 3. For each of the use cases, we take the perspective of a participant, the science organisation, and the researcher.

6.1. Designed environment: Tutti Insieme!! A general outline

General goal and outline of the environment: The exhibition with the title “Tutti Insieme!!” (All together) is part of a larger exhibition at Città della Scienza (a museum in Naples, Italy) on insects. “Tutti Insieme!!” focusses on the social behaviour of ants and the goals they can achieve through collaboration. The goal of the exhibition is to provide an overview of how collaboration between individuals can be understood as an evolutionary strategy and that collaboration is functional to the existence of the community and species. Apart from this main goal, visitors learn about ants and their life and engage in the science enterprise by interacting with parts of the exhibition, for example through a workbook that invites them to make fieldnotes during the exhibition.

The experience: Individuals, families, and schools can enter the museum and visit this dedicated exhibition about the social life of ants. The exhibition contains several stations that allow the visitors to inspect and observe the social life and behaviours of the ants. Figure 18, shows the station dedicated to the red forest ants (in Italian Formica rossa dei boschi). The red forest ants are well organized hard workers and their behaviour and work is an excellent example that together they can achieve remarkable things. In the exhibit, a terrarium is included, where it becomes clear that these ants built high anthills that are above the ground. The ants are not observable in their terrarium all the time; if they are in the ant hill, it is difficult to observe them. Video screens are available to provide people with the opportunity to observe ant behaviour if the ants are not visible. These screens can also highlight behaviours that are important but hard to observe.

Figure 18. *The red forest ants station at Città della Scienza*

6.1.1. The participant and the Science Chaser

The participant is a child that, together with the family, decides to visit Città della Scienza. Upon this decision, they visit the website and learn that they can download an app that will enhance their experiences at the museum. The father decides to download the app on the mobile phone of his child and they complete the registration procedure. Already at home or upon arrival at the museum, the participant opens the Science Chaser and selects the Città della Scienza from the list of associated organisations. Upon this action, the child sees a list with artefacts and artefact routes that he can interact with. The family decides to go to the Tutti Insieme!! exhibition and uses the suggested field notebook to enhance their experiences. The notebook was suggested by the Science Chaser after the child scanned the QR code at the entrance of the exhibition hall.

Before the notebook opens, the child is asked a few brief questions about the life of ants. During their visit to the exhibition, the child completes questions in the field notebook, studies ants, and writes down conclusions and observations. After the child completes the notebook, a reward is added to the gamification feature in the app. The family selects a few additional activities in the exhibition and interacts with them. For some parts, the child indicates that he would like to learn more. The Science Chaser suggests content that is more complex and the child studies it with his mother. When the family leaves the exhibition, they indicate this in the Science Chaser. This action triggers the system to provide them with a few brief questions about the exhibit.

Since the child visited the exhibition for more than 30 minutes and interacted with multiple artefacts, the Science Chaser will suggest follow up activities and provide him with a few updates in the form of pictures and facts about ants.

6.1.2. The science organisation and the Science Chaser

For the organisation, the Science Chaser is a tool to communicate with the participant, stimulate the participant to engage with the materials, and stay connected to the participants. In the Tutti Insieme!! exhibition, the organisations can interact with the participant by having them scan tags at the exhibition that reveal additional information either in text, image, or video format. The science organisation can do so by creating or adding artefacts through the Digital Toolbox manager and assigning it a scan code for defining the trigger to display the artefact (for instance after scanning a code).

For this specific exhibition, a workbook (a kind of field notebook) is available for primary school children and will be developed for older children. A digital version of the field notebook can be integrated in the app. This is facilitated by the questionnaire functionality that is available in the Digital Toolbox manager. The science organisation is responsible for creating this notebook. The actual notebook will be delivered as an artefact that participants can interact with. By assigning a scan code to the notebook, participants can select the notebook. Also, at other points in the exhibition, Città della Scienza can identify artefacts that allow for interaction with the Science Chaser. By providing language and age tags, we can suggest information that matches the language preference and age range of the participant. The created artefacts can be stand alone or part of an artefact route which Città della Scienza defined in the Digital Toolbox manager. Different routes can be defined, for example aimed at different target groups.

To stay connected with the visitors, the museum can use the app to send updates to users of the app. In the case of the exhibition on the social life of insects, the museum creates images and video material on a regular basis that can be shared through the app, with a bit of background information. This implies that Città della Scienza can suggest artefacts. The advised activities are based on the preferences of the participant and the artefacts the users interacted with during and

after the visit. For instance, the Science Chaser can send updates to former visitors of Città della Scienza (who used the Science Chaser).

6.1.3. The researcher and the Science Chaser

The researcher is interested in the actions of the participant and the impact on the six strands of science proficiency. During the interaction of a participant with the exhibition, the Science Chaser logs data about the participants' interaction with the artefacts. At a later stage, the data can be downloaded by the researcher. In this case, the research team wants to learn more about visitors' knowledge about insects and their behaviour. Therefore, the team defines an artefact route in collaboration with the museum. Upon entering the Tutti Insieme! exhibition, the visitors will receive two brief open-ended questions related to their prior knowledge about ants. They continue browsing the exhibition freely or guided by the aforementioned field notebook. In their route, the researchers not only included exhibition related artefacts, but they also included a few brief questions or self-reports. The Digital Toolbox manager allows the researcher to select the information they are interested in. In this case, the researcher is interested in primary school children that interacted with the exhibition (with or without the field notebook) to see the differences in the way they interacted with the exhibition and their outcomes with respect to science proficiency. The relevant data is selected and is downloaded for further analysis.

6.2. Outreach programme: WeSEM

General goal and outline of the programme: The WeSEM (Weizmann's educational Scanning Electron Microscope) project aims to provide learners direct access to science on the nanoscale. They do so through a remotely operated Scanning Electron Microscope. The project focusses on creating an authentic learning experience for the learners. Moreover, during the programme, students learn about scientific procedures and learn how researchers work with the Scanning Electron Microscope.

The experience: Secondary school classes can participate in an outreach programme consisting of five sessions. These sessions are implemented by their teachers in collaboration with scientists that use the SEM for their work. Students get the opportunity to examine their own samples through the Scanning Electron Microscope and to talk to scientists.

6.2.1. The participant and the Science Chaser

Together with the classmates and the teacher, a student is taking part in the WeSEM project. The Weizmann Institute asks the children to download and register with the Science Chaser before the first session. After creating the login and selecting both the science organisation and the WeSEM programme in the Science Chaser, students receive a few questions about their expectations and prior knowledge. The WeSEM project consists of several online sessions. After completion of a session, a student can report the session in the Science Chaser to receive gamification points. For the Science Chaser, this is also a trigger to present new information (for example a questionnaire). The children take part in the first online session and during this session the activity is explained. Upon completion, students are asked to tick off this activity in the Science Chaser and will be awarded for the activity through the gamification elements of the Science Chaser. After ticking off the session, the Weizmann Institute sends a brief summary with preparation guidelines through the app. In the subsequent sample-planning session, the teenager participates in an online meeting with a scientist that uses the SEM in his or her research. The scientist will talk about research and show examples. Guidelines for sample preparation are shared and students work in teams. The Science Chaser will provide them with a workbook that takes them through the process of sample preparation. This workbook basically is a questionnaire

in which the steps are represented by questions that can be ticked off or completed by the student. By completing the workbook, the students also document their process. When completed samples are delivered to the Weizmann Institute, students schedule a remote SEM-session to characterize their samples. After reporting the session, the students are asked to report their findings in the workbook. Again, they will be rewarded through the gamification element. The reported findings will serve as input for the summary and feedback session. Upon completion of the whole cycle, the students will again receive a brief questionnaire. For the students who participated in the session, updates about WeSEM related projects will be displayed in their artefact list. This, for example, can be some beautiful images that were made by the microscope and which are shared by the researchers.

6.2.2. The science organisation and the Science Chaser

The Weizmann Institute of Science in Israel creates an entry for the WeSEM project in the Digital Toolbox manager. Different artefacts are created and added through the Digital Toolbox manager. The artefacts (representing the sessions as well as the questionnaires and workbook) that are part of the WeSEM programme for this group of students are linked together in an artefact route that covers the programme as a whole.

At different points in the artefact route, students complete part of a workbook or fill in a science proficiency related questionnaire. An overview of the interaction with these artefacts can be requested by the science organisation.

6.2.3. The researcher and the Science Chaser

The researcher is interested in the actions of the participant and the impact on the six strands of science proficiency. Before participants interact with the activity, the researcher defines in the Digital Toolbox manager the different parts of the activity as well as the assessments (for example a scale or a semantic differential) and the timing of the assessments. During the outreach activities, data on participants' interaction with the digital workbook is logged, just as the information that the participant provided through the questionnaires. Upon starting with the outreach programme, the participant will receive and complete a few brief questions about topics related to their interest and prior knowledge. Depending on the interest of the research team and the goals of the activity, assessment can be more or less extensive. Different assessment instruments can be added through the Digital Toolbox manager. After the participants completed the outreach programme, the Digital Toolbox manager allows the researcher to select the information they are interested in and download it for further analysis.

6.3. Media contexts

6.3.1. The participant and the Science Chaser

During a family visit to the museum, a 14-year-old girl installed the Science Chaser app on her mobile phone. Some of her friends also have the app installed and she is interested in getting at least as many points in the app as her friends. She is interested in sustainability and therefore she watches a YouTube video on sustainable energy and reports this activity in the Science Chaser app. Her dad explains that wind has allows been an important source of energy and on the internet, they search for information about wind power and wind-powered power plants and explore a few articles on the website of the Davidson Institute (https://davidson.weizmann.ac.il/en/online/maagarmada/how-do-we-get-power-wind). She reports visiting the website in the Science Chaser app. Based on the reported activities, the Science Chaser app suggests related materials, including the wind energy simulation that is made

available in the Go-Lab learning environment (https://www.golabz.eu/lab/wind-energy-simulation). In this simulation, she controls a wind farm to provide electrical energy to a small town. Through this simulation she learns how random changes- in wind speed and power requirements of the town- affect the use of this natural energy source. The simulation is supported by one of the organisations in the project and after interaction with this artefact the girl is asked to complete a few questions.

6.3.2. The science organisation and the Science Chaser

In the scenario, we see that the girl interacts with media materials that have been provided by different organisations. The Science Chaser can suggest artefacts based on the individual's interaction with the Science Chaser. In this case, her interest in sustainable energy and wind energy resulted in the suggestion to check out the wind energy simulation, that is provided by one of the partners in the project. The science organisation added this activity to the Science Chaser and provided the appropriate tags and metadata. The activity is recognized by the system as relevant, because the metadata and tags were related to the (search) actions of the participant. Therefore, the backend included it on the list of advised artefacts.

6.3.3. The researcher and the Science Chaser

Researchers are interested in the type of media products participants interact with and the effect of these products on their science proficiency. The interest of the participant is reflected in the topics and type of media artefacts they interact with in the Science Chaser and they report in the Science Chaser. The 14-year-old girl is reporting multiple activities that are related to sustainability and energy. This signals her interest in those topics. All activities that she reports are accessible through the internet, she does not report books or newspaper articles. For the activities that are performed in the Science Chaser app, we can track the duration of her interaction with the media product. The researcher and the science organisation also use the Digital Toolbox to define that that after interaction with a specific artefact a short questionnaire should be presented.

Researchers are interested in the type of media products adolescents interact with. Therefore, they select the appropriate age range, and for this age range download all the self-reported media products as well as the data about interaction with media that is available in the Science Chaser app. For the latter category, they check the duration of the engagement.

6.4. Everyday life perspective

6.4.1. General outline

This perspective allows to capture the journey of a specific participant towards his or her science proficiency. This journey can be both inspired by the personal interests and intrinsic motivation and stimulated by the suggestions in the Science Chaser.

6.4.2. The participant and the Science Chaser

A 17-year-old girl living in Lisbon learns from friends about a new app that they were introduced to at school – the Science Chaser. She installs it to see what it does, even though she is not very keen on science; she likes history and architecture more. In the app, she is browsing through a list of suggested activities in her city and sees a tour to the historical building of the observatory (http://oal.ul.pt/atividades-e-servicos/visitas-guiadas-ao-oal/). As she likes history and architecture, she decides to go and invites her younger sister. When arriving at the observatory, she checks in with the app. During the tour, she learns more about the history and the modern

state of astronomy. After the visit, she is asked some questions in the app and gets some suggestions of similar activities. There she sees a visit to a planetarium (https://ccm.marinha.pt/pt/planetario). She decides to go there the other day and again registers this activity in the app. During the visit, she learns about light pollution, a problem she never thought of before. So she is browsing in the app to get more information about it. She is recommended some documentaries that she watches, but she also learns about the programme Dark Skies Rangers that is taking place in a different place in Portugal (http://dsr.nuclio.pt). The programme unites citizens who want to develop practical and feasible measures to decrease light pollution in their area. She decides to join the programme. As a participant, she needs to collect some data about light and dark every day, which she also registers in the Science Chaser. Slowly, she starts checking the Science Chaser on a regular basis to get some advice on the activities for her science classes at school, to register activities and get more points, to select more activities, and to upgrade her avatar. From time to time, the app suggests her some reflective questions about her attitude to science and usage of science in everyday life. She always answers them and slowly she sees that she becomes more engaged with it. She is still considering her future career in history and architecture, but now she sees how much scientific knowledge can bring to these areas.

6.4.3. The science organisation and the Science Chaser

As in the three other contexts, in the everyday life context, organisations use the Science Chaser to attract visitors, to promote their activities, and to make them more visible and influential for society. In the case of the 17-year-old girl, the organisations provided relevant links to activities in the area, which is a very good way to get more visitors interested in the same topic, being astronomy and light pollution in this case. When organisations place their activities in a bigger picture of science proficiency, they not only attract more visitors through cross-referencing, but also establish wider and broader connections between different organisations providing iSTEM activities.

6.4.4. The researcher and the Science Chaser

Researchers are interested in logging the pathways to science proficiency that different participants take, and what influence each activity on this pathway has on the choice of the next one. Collecting all the information about the self-reported activities gives an insight about the interests of a participant and the changes in them. And knowing which of the suggested activities a particular participant completes gives science organisations information about what is attractive and what is not. Reflective questions help to capture changes in the attitudes and affiliation with science that do not happen after one or two activities, but rather after being engaged with informal science learning for some time. These questions relate to the six strands of science proficiency and show the contribution of a set of iSTEM activities to mastering these strands.

7. Planning of future work

7.1. Timeline for the Digital Toolbox manager

In the current deliverable, we sketched the outline of the Digital Toolbox consisting of the Science Chaser and the Science Booster, and the Digital Toolbox manager. Steps that are taken in the following months (April/June) will involve the creation of a first version of the Digital Toolbox manager, so that science organisations can provide feedback on the functionalities of the Digital Toolbox manager and can start to enter content elements (including artefacts and assessment instruments).

7.2. Timeline for the Science Chaser

Starting May 2022, the work on the Science Chaser will start with the creation of a user interface that builds on the digital identity presented in D7.2. Mock up versions will be created and discussed first within WP3, and at a later stage (July/August 2022) within the entire consortium and with potential users. Adjustments will be made based on suggestions of project members and the experiences of the users. In September 2022, we plan to have a first functional version of the Science Chaser available. This version can be tested with the participants and science organisations.

7.3. Timeline for the Science Booster

The development of the Science Booster is planned for the last year of the project. This allows us to make use of the inventory, matrices, and success criteria that are identified and defined in WP2, as well as the data that is collected in the research that is implemented as part of WP4 Moreover, we can benefit from the experience of designing and implementing the backend, the Digital Toolbox manager, and the Science Chaser.

8. Conclusions

This deliverable has described the requirements and a first specification of the Digital Toolbox. The conceptual design and architecture described seems to match the requirements from different user groups in the project and within different contexts.

The different components of the Digital Toolbox facilitate flexible registration of users (project members, science organisation, and participants) and makes it possible to assign distinct roles and functionalities to specific user groups. Participants will be interested in performing and reporting activities in the Science Chaser. The design of the Science Chaser enables users to report their activities in and outside science organisations, engage with interactive elements that are part of the Science Chaser, and receive updates based on the activities they interacted with. Science organisations will be more interested using the Digital Toolbox manager to add and edit activities and content in the Science Chaser. The manager facilitates the science organisations to add content and to specify when the content should be shared with the participants. In a similar fashion, researchers can use the Digital Toolbox manager to add assessment schemes to the Science Chaser and download data. This is all facilitated and integrated in the design of the Digital Toolbox.

For the development of the Science Chaser, we will collaborate with WP4 (research implementation) and WP5 (impact assessment), to make sure that the functionalities of the Science Chaser are always in line with the research and assessment requirements.

The actual content and design specificities of the Science Booster are not fully defined in the current deliverable. This will be done in D3.2 (conceptual design of the Science Booster app), which is due in M36. In order to specify the structure of the self-assessment and advice functionalities, we need input from WP2 (research framework). The information that will be provided in deliverable D2.2 (definition of key characteristics) and D2.3 (the inventory and description of different iSTEM activities) will provide a basis for the further development of the Science Booster. These two deliverables are due in M12.

Based on interaction with the different user groups, the presented design of both the Science Chaser and the Science Booster can be slightly adjusted. Interaction with the users can, for instance, provide us with information on how science organisations like to manage their activities and what type of content management tools they prefer. The developments and results of this exercise will be incorporated in deliverable D3.4 (final release of the infrastructure and the Science Chaser app) and D3.5 (final release of the Science Booster app), which are both due in M36 of the project.