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Durall Gazulla, Eva; Bauters, Merja; Hietala, Iida

Report on the Helsinki co-design session

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SCIENCE LEARNING OUTSIDE THECLASSROOM

WP 4: IDEATE

Deliverable 4.1:

Report on the Helsinki co-design session

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Contributors	Merja Bauters, Iida Hietala
Images	Roya Ranjbar, Eva Durall
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Glossary of Terms

Acronym	**Definition**
WP	Work Package
STEM	Science, Technology, Engineering and Mathematics
STEAM	Science, Technology, Engineering, Arts and Mathematics
UCD	User Centred Design
PD	Participatory Design
TEL	Technology-Enhanced Learning
NGO	Non-Governmental Organization
DIY	Do It Yourself
D	Deliverable

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1 Introduction

The SySTEM 2020 project includes the development of research and practice tools in order to gain a better understanding of and to support science learning outside the classroom. The tools designed and developed as part of SySTEM 2020 are expected to be used in different contexts by a diversity of stakeholders involved in science learning.

Work Package 4 focuses on structuring the SySTEM 2020 ideation process and ensuring that the tools developed as part of the project contribute to science education by addressing critical challenges that learners face when engaging in science learning in informal and non-formal contexts. SySTEM 2020 uses co-creation and co-design as strategies to involve stakeholders throughout the ideation process and build a shared understanding on the critical challenges faced in science learning outside the classroom. The adoption of participatory techniques is also expected to support the identification of opportunities for improving science learning outside the classroom through the collaborative creation of concepts and ideas.

The research actions conducted as part of WP4 follow a qualitative approach. The aim is to understand how diverse people experience science learning and develop insights on the existent practices and ways to engage in STEM (Science, Technology, Engineering and Mathematics), as well as STE(A)M (the "A" standing for Arts). The outputs of WP4 feed WP5 and support the materialization of the design concepts into specific designs that could be developed and implemented in pilot tests.

This deliverable reports on the actions conducted in the SySTEM 2020 co-design process. It starts by introducing co-creation and co-design and how they have been implemented in the scope of the project. In particular, this deliverable focuses on the contextual inquiry and the co-design event that took place in Helsinki on March 2019 with the SySTEM 2020 project partners, stakeholders and science learners. Findings from the analysis of the Helsinki co-design event are also presented and formulated as recommendations for the design of tools in WP5.

2 Considerations on co-design and co-creation

Despite their apparent similitude, the terms co-design and co-creation should be distinguished as they come from different fields, and therefore the vocabulary, as well as the centre of interest of each of them varies (Marttila & Botero, 2013). While co-design comes from the design tradition and is influenced by cooperative design, co-creation connects to work on management and marketing studies. Whereas the relation between designers and the design beneficiaries is a central part of the co-design processes, in co-creation the emphasis is in how to create and retain value. (Marttila & Botero, 2013).

A central aspect of co-design and co-creation deals with involving the design beneficiaries throughout the design process. While questions like when and how often the participatory activities should take place remain open, special emphasis is placed on supporting meaningful participation. Thus, issues like the participants' roles, as well as to what extent they are able to take ownership becomes critical to assess the sustainability of the design solutions (David, Sabiescu & Cantoni, 2013; Muller, 2009; Roschelle & Penuel, 2006).

Scholars have defined co-design in different ways (Mattelmäki and Visser, 2011). Although all the approaches advocate for involving the design beneficiaries during the design process, some perspectives draw more heavily from the User Centered Design (UCD) and the Participatory Design (PD) tradition to stress the importance of democratic participation and user empowerment (see Ehn [2017] and Spinuzzi [2005]). In turn, other approaches have addressed the attention on the methods and the tools used to support people's participation and sharing (Sanders, 2002). Because of the collaborative work in which designers and end-users engage, co-design has also been described as a collaborative creation process (Sanders & Stappers, 2008). Plus, the inclusion of other stakeholders, in addition to the people who would be directly affected by the design, has also been advocated as a way to gain insights on people's experiences (Sanders & Stappers, 2008).

In co-creation, value is created through shared experiences characterized by high-quality interactions based on dialog, access and transparency (Prahalad & Ramaswamy, 2004). Similar to co-design, there is strong emphasis on ensuring that all the interacting parties engage in horizontal relationships and thus, can build equal relations that allow them to collaborate and learn together. From this standpoint, co-creation is an overarching concept that refers to openness and a creative mindset. From a design perspective, co-creation has been described as collective creativity (Sanders & Stappers, 2008).

When connecting co-creation to co-design, co-design can be understood as a "specific instance of co-creation" (Sanders & Stappers, 2008, p.6). As noted by Mattelmäki and Visser (2011), such instances may take the format of workshop events in which stakeholders engage in co-design and collaboratively explore, plan and learn about a specific issue. It is worth to note that from other perspectives, co-creation has been also considered as a co-design method, which is focused on the creation of solutions (Van der Lugt et al., 2009).

In SySTEM 2020, co-creation is understood as a method with a creative atmosphere in which designers and stakeholders engage in co-design events where they collaboratively explore, develop shared understanding, as well as generate solutions and design concepts for the jointly identified challenges. The adoption of a cooperative design approach in the SySTEM 2020 project was considered a suitable strategy for involving the people who would be affected by the project outputs and therefore, ensure that the solutions created would be a meaningful contribution that answers their needs and wishes. In particular, supporting stakeholders' active participation at key moments of the ideation process aimed to ensure the use, usability, and utility of the design solutions.

In Technology-Enhanced Learning (TEL), scholars have advocated for the use of cooperative design approaches like co-creation and co-design when designing tools for learning (Bonsignore, Ahn, Clegg et al., 2013; McNally et al., 2018; Leinonen, Toikkanen & Silfvast, 2008). Due to the influence of the UCD tradition on co-design, the last one is considered to align well to learner-centered design (Penuel, Roschelle & Shechtman, 2007). Recent initiatives in the design of tools and services for children also recognize the need to actively involve children and their communities in the design process (see the Design for Children's Rights Association recommended methods and practices[1]).

Co-design is increasingly used in the design of tools for learning, as it provides opportunities to actively involve education stakeholders and draw from their expertise (Roschelle & Penuel, 2006). According to Penuel et al. (2007) co-design is "a highly facilitated, team-based process in which teachers, researchers, and developers work together in defined roles to design an educational innovation, realize the design in one or more prototypes, and evaluate each prototype's significance for addressing a concrete educational need." (p.53). From the authors' perspective, co-design brings together people with different expertise and interests and therefore, is a good strategy to balance tensions between practitioners and researchers and create ownership of the solutions generated (Penuel et al., 2007).

In science education, participatory design and co-design have already been used in curricula design (Shrader, Williams & Lachance-Whitcomb, 2001; Ye, Zhang & Chia, 2010), to design assessment tools (Penuel et al., 2007, Yarnall, Shechtman & Penuel, 2006), as well as mobile tools that support collaboration (Maldonado & Pea, 2010; Spikol et al., 2009) and inquiry-based learning in science education (Zhang et al., 2010). Based on the high number of science education research and innovation initiatives that incorporate user participation as a central aspect of the design process, in the SySTEM 2020 project co-creation and co-design were considered reliable methods for the design of tools that supported science learning outside the classroom.

[1] See the section on methods and practices of the Children Design Guide available at the Designing for Children's Right site: https://childrensdesignguide.org/methods-practices/

3 SySTEM 2020 co-design process

3.1 Overview

The co-design process conducted in the SySTEM 2020 project can be separated in three different phases consisting in 1) Contextual inquiry, 2) The Helsinki co-design event and 3) Analysis of the co-design outputs (see figure 1).

Figure 1. Images of the SySTEM 2020 co-design process.

Cooperative design processes typically start with an inquiry on the context of use (Leinonen et al., 2008; Penuel et al., 2007). Understanding the current practices of the potential beneficiaries, as well as the preliminary challenges is important in order to define the design space and identify design opportunities. In this regard, the contextual inquiry can be characterised as preliminary work usually consisting in fieldwork in which design researchers adopt rapid ethnographic techniques (Hughes et al., 1995; Millen, 2000). The data collected during the contextual inquiry is analysed and used to inform participatory activities with the stakeholders.

In design, the stakeholders are the people, groups and individuals, who may be affected by the outcome of a project. While they may have different interests and expectations regarding the project outcomes, their involvement and active participation throughout the design process is critical for the project success. The SySTEM 2020 project's direct stakeholders are organizations and groups connected to science learning such as science museums, makerspaces, libraries, but also individuals like learners (whether they are currently involved in science learning or not), educators and facilitators, amongst others.

In SySTEM 2020 the analysis of the data collected during the contextual inquiry was used to inform the themes and materials used during the Helsinki co-design event (see section 3.1 for further description of the contextual inquiry conducted before the Helsinki co-design event).

Taking time for developing shared experiences is a critical part of co-design and co-creation processes (Penuel et al., 2007). Co-design workshops are a popular format in which stakeholders, design researchers and developers gather in order to build a shared understanding of the issue at hand, as well as the opportunities and challenges related to it. As highlighted in research on co-design and participatory design, key challenges to take into consideration in co-design events deal with finding a common language among participants with diverse expertise (Luck, 2003; Moser, 2016), supporting effective collaborative teams (Détienne, Baker & Burkhardt, 2012), managing expectations (see Tomico and Garcia [2011]), as well as ensuring that everyone has the opportunity to participate in a meaningful way (King et al.,1989). Furthermore, it is important to acknowledge that inclusiveness and creativity are at the centre of co-design, rather than efficiency and effectiveness (Moser, 2016). As noted by Moser (2016), building an inclusive and creative environment, in which participants feel comfortable and trustful requires time.

As Sanders and Westerlund (2011) suggest, co-design events tend to happen at early stages of the design process in order to engage designers and non-designers in creative work around complex challenges. The co-design activities can be oriented towards sharing experiences and collaborative sensemaking, as well as towards finding potential directions that can help framing the design space. In SySTEM 2020, a co-design event with project partners, learners and stakeholders in science learning outside the classroom was organised on the 18th and 19th of March, 2019 in Helsinki. The aim of the meeting was to actively involve all partners to collaboratively explore and develop a shared understanding of the main challenges and opportunities to support science learning outside the classroom (see section 3.3 for a detailed explanation of the co-design event organised as part of the SySTEM 2020).

Documenting the co-design event discussions and ideas is key as these data would be analysed by design researchers to gain further insights. In design, the interpretation of the data is typically based on synthesis, an inference-based sense-making process. According to the definition provided by Jon Kolko, “Design synthesis attempts to organize, manipulate, prune and filter gathered data into a cohesive structure for information building” (Kolko, 2007, p.1). Re-examining the data from different perspectives, making connections and developing new insights are the core activities of design synthesis. To gain understanding and engage in idea generation, designers use design synthesis methods like reframing, concept mapping and insight combination (Kolko, 2010). The analysis of the data collected during the SySTEM 2020 contextual inquiry, as well as in the Helsinki co-design event was performed through qualitative analysis methods like thematic analysis. We consider that outcomes reported in this document are a starting point for further design work that uses design synthesis to materialize solutions in specific tools and materials.

In co-design, design researchers are responsible for analysing and interpreting the data produced during the co-design event, which consists of user-generated artefacts and models (Sanders, 2002). For this reason, it is important to acknowledge designers’ accountability on the quality of the resulting products and services (Howard & Melles, 2011). Thus, the decision making on aspects like the requirements definition as well as a potential technology assessment is left to the designers and developers. Ensuring transparency in the decision-making process and allowing stakeholders to further contribute to the process is also important. For this reason, in SySTEM 2020, partners and stakeholders have been given access to the information concerning the ideation process. The project partners and stakeholders are also expected to influence the process by giving feedback to the design results that are shared throughout the project.

3.2 Contextual inquiry

During the contextual inquiry, design researchers aim to immerse in the context and gain understanding in order to define the preliminary challenges (Beyer & Holtzblatt, 1998; Leinonen et al., 2008). According to Beyer and Holtzblatt (1998), "Staying in context enables us to gather ongoing experience rather than summary experience, and concrete data rather than abstract data." (p.47). To this purpose, design researchers adopt ethnographic methods to learn about the context of use, the existing practices, as well as the interrelations between individual and group behaviours (Blomberg et al., 2017).

Traditionally, ethnographic research provides rich descriptions of a specific situation. In this regard, ethnography follows a qualitative approach and takes place during an extended period of time. In design, the constraints (of time and resources) for conducting an ethnographic study have led to the adoption of a 'quick and dirty' approach to ethnography, characterised by short periods of fieldwork and the development of focused studies (Hughes et al., 1995). According to Millen (2000), rapid ethnography involves diverse field practices that allow designers gain understanding in a shortened period of time through focused observation, careful selection of informants and by involving several researchers in the data collection and analysis process.

During the SySTEM 2020 contextual inquiry, we used rapid ethnographic methods, such as participant observations in different non-formal and informal science learning contexts, and conversations with different degree of formality, ranging from casual talks to semi-structured interviews with individuals and groups. The conversations were documented using textual notes and audio recordings that were analyzed later on. In the case of the semi-structured interviews, the people contacted were carefully selected. In several cases, we were able to develop "long-term informant relationships" (Millen, 2000) that resulted in the informants' involvement in multiple occasions (for instance, for providing feedback during the design of the SySTEM 2020 map of WP2, as well as joining the final sharing session of the co-design event held in Helsinki).

The field observations conducted as part of the SySTEM 2020 contextual inquiry were performed by a research team formed by three researchers. In order to ensure that the observations provided actionable data, the researchers aimed to answer to specific questions through the fieldwork. Observation templates (see the appendix 1) were created and shared with the research team to ensure the observations had the same focus. To triangulate the data, the field notes and interviews were complemented with questionnaires and visual data, such as photographs.

Prior and parallel to the fieldwork, the research work included a review of existing research on science education and learning in different contexts. This review had a broad focus in order to get a general overview of the state of the art, as well as of the main issues and findings presented in previous research. Also, we identified current trends in science learning outside the classroom, as well as tools and designs to support learning in non-formal and informal contexts.

In the following subsections, we provide detailed information on the focus and the data collection actions that took place during the SySTEM 2020 contextual inquiry. While the insights gained through the use of rapid ethnographic techniques helped to identify main challenges and design directions, we acknowledge the “impossibility of gathering a complete and detailed understanding of the setting at hand” (Hughes et al., 1995, p.6). Additional challenges are related to the fact that all data was collected in Finland, in the southern area. Because of this limitation, it was not possible to transfer the research findings to other countries. For this reason, the findings were kept as a hypothesis and used to inform the materials that supported the discussions during the co-design event. The feedback provided by the stakeholders, as well as the outputs created during the co-design event helped to validate the contextual inquiry results.

3.2.1 Objectives

The SySTEM 2020 contextual inquiry aimed to provide a broad understanding of science learning outside the classroom. To this purpose, the research actions conducted aimed to:

- Map the most common contexts, activities and participant groups in science learning outside the classroom.
- Identify issues that children and youngsters face when accessing and engaging in science learning, as well as the key aspects that play a role in supporting motivation and engagement of different groups.
- Spot the most common backgrounds and characteristics of the science educators and facilitators working in non-formal science education.
- Pinpoint the main challenges that facilitators and educators of science learning activities face in their everyday work.

During the SySTEM 2020 contextual inquiry, the observations and data collection actions focused on:

- The **contexts** outside the classroom that offer opportunities for science learning. We paid attention to aspects like the accessibility of the spaces, the communication outreach, the organizational structure, as well as guidelines and policies for supporting inclusion.
- The **activities** offered in the above-mentioned science learning contexts. In particular, we focused on the contents, the format, the target groups, the level of complexity of the tasks, as well as the required equipment for performing the activities.
- The **participants**. We noted which groups[2] predominated, as well as their attitudes and behaviors. We paid attention to the diversity, background, and demography of the participants. By identifying who was present, we also noticed which groups were absent from our fieldwork observations.
- The **facilitators and educators** that lead the science learning activities outside the classroom. We observed what type of backgrounds and demographic factors tended to predominate. We also paid attention to their facilitation style, their involvement in the activity design, as well as their sensitivity to issues connected to inclusion, and how to support engagement and motivation.

[2] We took into consideration aspects like age, gender, ethnicity as well as the spoken language to make a rough description of the groups.

By observing these aspects we aimed to immerse in non-formal and informal[3] science learning contexts, as well as identify the main challenges that might hinder engagement and participation. Simultaneously, by developing a clear picture of the existing practices, we were able to pinpoint some opportunities for action that require further exploration.

3.2.2 Contexts and stakeholders

In the SySTEM 2020 contextual inquiry, we have taken into consideration the following science learning contexts: makerspaces in public libraries (n=4), a hacklab, a maker festival, summer camps (n=2), science museums, a robotics centre, as well as after-school science programs and activities offered by youth centres and local organisations. The observations took place in Finland, in the Helsinki metropolitan area over a period of 4 months.

At European level, we took into consideration data about project partner institutions and their activities (n=19). In addition, the data from 29 European organisations collected for testing the SySTEM 2020 map organisations' forms was included in the analysis in order to contrast it with the data collected in the Finnish context[4].

As part of the field research, we collected information about learners (n=45), parents and guardians (n=20), science educators and facilitators (n=49), pedagogical coordinators (n=7), activists and makers (n=22), people working in Non-Governmental Organizations (NGOs) focused on groups at risk of social exclusion (n=2), as well as people working in local and professional organizations focused on promoting science learning (n=5). Although many of the people observed or interviewed resided in Finland, we tried to collect information also at the European level[5] to prevent the findings being biased towards the characteristics of the Finnish context.

Since the contextual inquiry aimed to offer a broad contextual understanding of science learning outside the classroom, the age group of the learners taking part in those activities and events was not taken as a limiting criterion. However, taking into consideration that the SySTEM 2020 project focuses on a specific age range (from 9 to 20 years old), we tried to ensure that data about these age groups was collected during the contextual inquiry. Below, we specify the actions conducted to gather data about the different age groups of interest in the SySTEM 2020 project (see table 1).

Table 1. Age groups considered in the SySTEM 2020 contextual inquiry

Age group	Context	Research action	Number of people
2 to 14 years old	Maker festival	Field observations and informal interviews	12
9 to 14 years old	Science summer school	Field observations	28

[3] See deliverable 2.1 on the SySTEM 2020 conceptual framework for a definition and further elaboration of informal and non-formal learning frameworks based on a systematic literature review.
[4] In these cases, the design of the questionnaires and the data collection were part of the WP2 tasks.
[5] The online questionnaire addressed to educators working in non-formal education science organizations was answered by people from 19 European countries. Also, the questionnaire submitted to european organizations (n=29) involved in STEM and STEAM non-formal education provided data that helped to understand the context at European level.

5 to 17 years old	Science museum exhibitions	Field observations	50
19 to 21 years old	Vocational school (media engineering)	Focus group	5

3.2.3 Data collection

The methods used for collecting data consisted of informal and semi-structured interviews, focus groups and field observations (see table 2).

Table 2. Stakeholder groups and data collection methods used during the contextual inquiry

Stakeholder group	Data collection methods	Data format	Number of people
Learners	Focus group with vocational school students	Audio and video, notes.	5
	Observations of participants attending to two summer camps	Images, notes.	28
	Informal interviews and observation of participants in a maker festival	Notes	12
	Observations of people attending to a science museum exhibitions	Images, notes	50
Parents and guardians	Observations and casual conversations to adults accompanying children to a maker festival.	Notes	15
	Observations of the adults attending to the final exhibition of two summer camps (Aalto Junior)	Notes	5
Science educators and facilitators	Observation and informal interviews to facilitators in two summer camps	Notes	8
	Semi-structured Interviews with science museum facilitators	Audio	4
	Online questionnaire to educators working in non-formal science organisations	Digital text	37
Pedagogical coordinators	Group interview with a science museum staff	Audio	3
	Semi-structured interviews with public libraries personnel	Audio, notes	3
	Semi-structured interview with the coordinator of a robotics centre	Notes	1
NGOs workers working with	Semi-structured interviews	Audio, notes	2

minority groups in science education (immigrants, refugees, young people at risk of social exclusion)			
Activists and makers running activities in hacklabs	Questionnaires and semi-structured interviews with makers participating in a maker festival	Text, notes, images	19
	Observations and semi-structured interviews in a hacklab	Notes	3
Local and professional associations	Focus group	Notes	5

Three researchers were involved in the SySTEM 2020 data collection for the contextual inquiry. The field observations were conducted by two researchers who simultaneously took notes, and in some cases, images of the situation. After the field observations, researchers shared their notes and discussed their views on the situations at hand.

Most of the interviews were conducted by two researchers[6]. In the cases in which the interview had been audio recorded, one of the researchers either transcribed the audio or wrote a textual summary of the interview. These texts were shared and commented by the other researchers.

In total, about 200 people were observed and/or approached during the contextual inquiry phase. The type and formality of the contact with these people varied from casual conversations to interviews and questionnaires. We provided information about the research and requested permission to conduct observations of the activities organisers and people in charge in the above mentioned contexts. In the cases in which people were interviewed, they were informed about the research purposes and asked to sign a consent form[7].

3.2.4 Analysis and results

The data collected during the contextual inquiry was analysed using a qualitative approach. In particular, we conducted an inductive thematic analysis that led to the definition of the following themes: needs and interests of different stakeholders, educators' background and their pedagogical practices, spaces and equipment, activities, tacit assumptions about science, values, collaboration, skills, assessment, as well as monitoring and tracking.

[6] One of the researchers led the interview in a semi-structured way, while the other researcher took notes, recorded the session and intervened to raise or follow up specific issues that were considered relevant.

[7] The research conducted in this study followed the guidelines of the Finnish Advisory Board on Ethical Principles of Research in the Humanities and Social and Behavioral Sciences and Proposals for Ethical Review (2009).

After a careful examination of the themes, we defined three main challenges in non-formal science learning: barriers to access scientific culture, challenges connected to learners' self-concepts, and challenges for sustaining interest in science learning.

First, it is important to acknowledge that socio-cultural aspects pose significant barriers for accessing scientific culture. While in the metropolitan areas it is possible to find offerings that are accessible and free (or at low cost), still some groups tend to be missing, for instance people at risk of social exclusion or people who have disabilities. The underlying reasons that hinder participation are complex and vary among the different groups, ages and other factors. For instance, as observed in a science festival children's participation in science activities is strongly mediated by their parents and guardians. However, focusing on ensuring free access and communication outreach might not be enough to make certain groups and individuals feel included and willing to participate in science activities.

Based on the data collected from the interviews, we noticed that the definition of "science" is not straightforward for people who are not involved in science. For instance, the analysis of the focus group with vocational school students unveiled the difficulties that young people have to identify what counts as science, as well as the interrelations between the different disciplines included in STEM. We consider that such a lack of scientific literacy might pose serious challenges for engaging in science learning. If people are not able to define what science is, it is very difficult to identify ways in which they can relate to these areas. This means they do not have - or they are not able to identify - personal experiences connected to science that can be used to develop interest and help them identify as science learners.

Considering that children's access to science activities outside the school is mediated by their parents and guardians at an early age, the scientific literacy of the last ones is key to determine the access that young kids may have to science. It is worth noticing that guardians' scientific literacy has an impact on children's access to science activities, but also influences children's interest in science. For instance, during our observations at the maker festival, we noticed that the children participated (or played with the tools and objects) when the parents and guardians were actively participating and engaging in the activity. Thus, we concluded that in many cases, children's participation in a specific maker activity was determined by their parents' personal interests and abilities to engage in the task.

Second, regardless of the skill level, identifying oneself as a "science person"[8] is key to access and participate in non-formal and informal science learning. Yet, many out-of-school STEM activities take place in already formed communities and groups, like for instance after school clubs or community spaces like hacklabs. Quite often, the members of these groups have strong identities and pursue specific interests. For outsiders, joining these groups is challenging, as in a way, these groups are a part of a subculture. Without a self-identity related to science, even the mere act of finding entry points to join these groups (or the contexts/activities in which these groups tend to engage) might be challenging. For the teenagers or older groups, it might be particularly hard to "become" a maker or a hobbyist, and to join one of these communities.

[8] As noticed during the field observations and interviews, alternative terms used by the people to describe themselves are "hobbyists", "makers", "inventors", "DIYers" etc.

In addition, external views about science (even if stereotypical and reductionist) are worth to be taken into consideration for understanding the absence of certain groups in science events (like teenagers). For instance, for some groups of teenagers, STEM activities might be considered as profoundly related to school culture and “nerdy”, and thus, they might not be regarded as appealing or popular. In this regard, STEM activities are “competing” with other free-time activities, such as sports, hanging out with friends or socializing through social media. Considering the influence that social pressure has at certain ages, social perceptions of science might hinder certain groups and individuals from engaging with and participating in science learning activities.

Science (and STEM by extension) are a world in itself and have a specific culture. Based on the observations and interviews conducted in Finland, we infer that the dominant view is that science is male-oriented, has its own jargon, and is primarily intended for middle-class people from well-educated families. This view connects to previous research findings on inclusion in science (see for instance Achiam and Holmegaard [2015], Archer et al. [2010] and Ulriksen [2009]). To challenge such stereotypical views and actively engage, one needs to have experiences that support positive attitudes towards science, science knowledge, resources and referents and opportunities to engage in science. The sum of aspects that play a role in people’s exposure and knowledge about science has been defined as science capital (see Archer et al. [2015]). Based on the observations conducted during the contextual inquiry we consider that science capital is a relevant concept to understand how people relate and engage to science learning.

Past experiences in science are part of a person’s science capital and have a significant impact on people’s self-concepts. For instance, school memories - whether they are good or bad - seem to have a strong influence on how capable a person is, and what kind of self-esteem a person has, to identify herself/himself as a science person. However, while school memories were linked with experiences that people clearly associate with science, we noticed a lack of awareness of everyday situations that might be connected to science. People’s unawareness of past positive experiences in which they have been exposed to science prevents them from developing positive attitudes and connecting with others to share their experiences.

The role models and encouragement to pursue science interests are also part of the science capital a person might have. In the focus group interview, the vocational school students mentioned that along with their families, their school teachers in the earlier grades had played a role in their development of interest in science. In the interviews with social workers working with groups at risk of social exclusion, but also in the casual conversations with the maker festival participants, we acknowledged the key role of families for providing referents that can lead and support further engagement in science activities outside the classroom. Based on these observations, we concluded that some aspects of science capital are “inherited”. Thus, for the people who lack this “inherited social capital”, it might be quite challenging to self-motivate themselves and overcome the barriers to engage in science activities.

Main barriers for engaging in science learning are not necessarily connected to economic resources, but to the availability of time and information. As the students interviewed in a focus group acknowledged, learning about STEM is difficult and time consuming. Somewhat similarly, a social worker working with teenagers at risk of social exclusion remarked that some youngsters lack patience and persistence when trying to achieve things in their lives. Despite that it might not be openly stated, some communities and self-organised groups connected to making and doing require their members to be active in participating, sharing, or collaborating. Having the necessary time to obtain information and actively participate in the community might be challenging for people at risk of social exclusion, who already feel stressed in other areas of their life.

Understanding that there are many ways to get involved in science as well as to apply scientific knowledge are important aspects that affect people's self-concepts as "science persons". This is essential for avoiding feeling overwhelmed by not being enough skilled to perform certain tasks or feeling frustrated for having to reproduce a particular way of thinking. In this regard, transdisciplinary approaches (like STEAM) use art to support different ways to engage with science. However, in many cases, the artistic component is considered as craft work and reduced to the aesthetic tuning of the final artefact.

Third, the learners' ability to self-direct their learning about science topics is related to their ability to sustain their interest over time. Building on the observations conducted during the contextual inquiry, the challenge is not to create interest but to maintain it over a period of time. In the interviews conducted with the science educators and pedagogical coordinators working in non-formal science education, they acknowledged using surprise as a strategy for triggering participants' interest. Such strategy is known as the wow-effect and is widely used in science education, particularly in science museums. According to the interviewees, despite these experiences potentially having a strong impact on participants and even becoming life memories, the extent to which they support deep understanding and lead to further efforts to learn about science topics is not clear. While the wow-effect might be an effective strategy for short-span interactions, there is a gap about how to encourage and support learners to sustain their interest in science on the long-term.

Keeping motivation over time is connected to the goals learners set for themselves. In this regard, not understanding the benefits and professional careers connected to STEM subjects might be something that affects learners' interest in these areas. Despite developing a rich picture of the professions connected to science, the main challenges for sustaining learners' interest seem to be connected with self-regulation and self-assessment. Being able to set attainable goals, ask for help, and identify the resources needed to accomplish a task, for instance, are part of the issues studied in self-regulated and self-directed learning. Despite the important body of research on self-regulated learning, supporting learners' ability to self-regulate was not a primary goal in the science education activities outside the classroom. A possible explanation could be that science activities in non-formal education tend to have a short duration, and therefore, the educators focus on triggering the participants' curiosity and ensuring they have a positive experience, rather than training more complex metacognitive skills.

The insights gained through the qualitative analysis of the data collected during the contextual inquiry informed the design of the materials used during the co-design event held with project partners, learners and stakeholders in Helsinki. In the following section, we describe the event and provide information about the participants, the facilitation, as well as the methods and materials to support participation.

3.3 Helsinki co-design event

3.3.1 Objectives and structure of the co-design event

The Helsinki co-design event was held on the 18th and 19th of March 2019[9] in Helsinki, at Aalto School of Arts, Design and Architecture. The event gathered 49 people and involved the project partners, learners and stakeholders from different organizations related to science education outside the classroom.

The co-design event aimed to build a shared understanding of the challenges and opportunities in the non-formal and informal science learning, as well as to generate design concepts. In this regard, the event was an opportunity to share experiences about science learning outside the classroom, collaboratively explore the main challenges and engage in collective sense-making. Fostering collective creativity was another important objective of the meeting.

The event was organised around three areas that were considered relevant for science learning outside the classroom: inclusion, engagement, assessment and recognition of learning. These areas had already been specified in the SySTEM 2020 project description and they were considered relevant for guiding the data collection actions conducted during the contextual inquiry. Despite the many interrelations between inclusion, engagement, assessment and recognition of learning, it was considered relevant to address each of them as separate themes to ensure that the participants had the opportunity to discuss and elaborate on each. In order to ensure that the co-design event outputs were relevant for further work to be developed in WP5, the project members leading tasks in WP5 (SGD, ZSI) were invited to comment and give feedback on the structure of the event, the materials and activities, as well as on the expected outputs.

The Helsinki co-design event adopted a workshop format with working sessions focused on specific tasks. The first day sessions revolved around the challenges and opportunities for supporting inclusion, engagement, assessment and recognition of science learning outside the classroom. On the second day, the participants created design concepts that addressed some of the challenges and opportunities identified on the previous day (see table 3 for a detailed description of the agenda for the two days of the co-design event).

While participation to the co-design event was limited to staff from project partners, as well as the learners and stakeholders invited by the practice partners, the final session was open. We sent personal invitations to the informants addressed during the contextual inquiry. In particular, the representatives from makerspaces in public libraries, organisations offering STEM and STEAM activities, and individuals working with immigrants and refugees, as well as with people with disabilities attended the Helsinki co-design event final sharing session and joined the discussions.

[9] This corresponds to month 11 of the project timeline.

Table 3. Agenda for each of the 2-days co-design event

DAY 1: Monday 18th of March		
Start time	**Activity**	**Duration**
13:00	Welcome and general introduction	10 min.
13:10	Presentation of the SySTEM 2020 map	15 min.
13:25	Icebreaker	15 min
13:40	Picking badges and groups formation	10 min.
13:50	Icebreaker inside the groups	15 min.
14:05	Building a conceptual map	45 min.
14:50	Break	15 min.
15:00	Identifying challenges and opportunities	60 min.
16:00	Prioritization of opportunities	25 min.
16:25	Presenting challenges and prioritized opportunities	30 min.
17:00	Thanking and closing the session	
18:30	Social event	
DAY 2: Tuesday 19th of March		
09:00	Welcome and program for the day	5 min.
09:05	Selection of opportunities	10 min.
09:15	Ideation of design solutions	2 h. 15 min.
11:30	Assessing the design solutions	30 min.
12:00	Iterating the design solutions and preparing the final presentations	30 min.
12:30	Co-design workshop closure: Sharing the work and discussing the design solutions	1 h. 30 min.
14:00	Thanking and farewell to the learners, stakeholders and third parties	

3.3.2 Participants

Participants to the co-design event came from 19 countries from Europe and the Middle East[10]. Among the 49 participants, 29 people represented the project partner institutions (research,

[10] One of the project partner institutions is from Israel.

practice and third party partners), 12 people were learners invited by practice partners and eight were stakeholders (see table 4).

The SySTEM 2020 practice partners were required to invite three people external to the project, who had some involvement with the institutions as a learner or as a stakeholder[11]. In one case, due to legal restrictions for travelling in the European Union, the practice partner[12] could not invite learners as their refugee status did not allow them to travel outside Greece. We tried to compensate for the absence of learners with the refugee status by inviting a stakeholder connected to LATRA with wide experience working with this collective in the Greek context. In addition, the attendance to the co-design final session of an NGO worker who is knowledgeable of the situation of immigrants and refugees in Finland, and had organised STEM activities for these collectives, helped to expand the view of the specific challenges that migrants and refugees face by providing feedback from a different context.

Table 4. Institutions and roles of the Helsinki co-design event participants

Institution	**Role in the SySTEM 2020 project**	**Number of people and their roles in the Helsinki co-design event**	**Country**
Science Gallery Dublin	Research & practice partner	3 staff 2 learners 1 stakeholder	Ireland
Waag Society	Practice partner	2 staff 2 learners 1 stakeholder	Netherlands
Ars Electronica	Practice partner	1 staff 2 learners 1 stakeholder	Austria
Kersnikova Institute	Practice partner	1 staff 1 learner 1 stakeholders	Slovenia
Museo Nazionale Scienza e Tecnologia Leonardo da Vinci (MUST)	Research & practice partner	1 staff 2 learners 1 stakeholder	Italy
LATRA	Practice partner	1 staff 1 stakeholder	Greece
Centre for Promotion of Science (CPN)	Practice partner	2 staff 1 learners 1 stakeholder	Serbia
Bloomfield Science Museum	Practice partner	1 staff 2 learners 1 stakeholder	Israel

[11] The practice partners were encouraged to invite to the co-design event 2 learners and 1 stakeholder. The distribution of participants' roles varied depending on the possibilities of each institution.
[12] This was the case of LATRA, an NGO working in a refugee camp in Lesvos (Greece).

Centre for Social Innovation	Research partner	1 staff	Austria
Ecsite	Communication & dissemination partner	2 staff	Belgium
European Molecular Biology Laboratory	Third party partner	1 staff	Germany
Raumschiff — Werkstatt für Astronomie (Spaceship — the Maker Space for Astronomy)	Third party partner	2 staff	Switzerland
Fundação da Juventude	Third party partner	1 staff	Portugal
Muzeiko Foundation	Third party partner	1 staff	Bulgaria
TRACES	Third party partner	1 staff	France
uTesla	Third party partner	1 staff	Czech Republic
Flanders Technology International (Technopolis, the Flemish Science Centre)	Third party partner	1 staff	Belgium
Thessaloniki Science Center and Technology Museum NOESIS	Third party partner	2 staff	Greece
Tom Tits Experiment	Third party partner	2 staff	Sweden
Parque de las Ciencias	Third party partner	2 staff	Spain

The participant recruitment was organised by the practice partners. Prior to the co-design event, the practice partners responsible for arranging the invitations to learners and stakeholders received some guidelines from the Aalto team organising the co-design event. In the case of the learners, it was specified that they would be between 18 to 20 years old and they would have a minimum understanding of English. In order to ensure that participants had diverse backgrounds, practice partners were asked to take into consideration gender balance, and invite learners with different levels of engagement with the institution, interest on scientific careers, cultural background and socioeconomic status. In the guidelines, it was suggested to invite people whose families were not involved in STEM careers in order to bring to the co-design event the views and needs of people without close role models in science. Due to the limitations in adapting the activities for people with cognitive disabilities, it was decided not to invite people with severe cognitive impairments. Instead, the practice partners were encouraged to invite stakeholders who had expertise working with people with special needs based on their work experiences.

The SySTEM 2020 stakeholders consisted of people with experience in science education outside the classroom in contexts like science museums, science dissemination centres, science festivals, makerspaces, fablabs, and hackerspaces, to name a few. In many cases, the stakeholders were educators and facilitators working in these contexts, but they could also be activists, artists, makers, pedagogical coordinators or other roles of people working in communication or management departments of non-formal science education institutions. While all people involved in SySTEM 2020 can be considered as stakeholders, with this term we refer to people who are involved in science education outside the classroom, but who are not involved in the everyday work of the SySTEM 2020 project.

The guidelines for inviting stakeholders to the Helsinki co-design event consisted in a checklist of criteria that were considered important for ensuring meaningful participation. Amongst these criteria figured language skills, and experience working with children and teenagers in multicultural contexts. In order to ensure diversity, practice partners were asked to invite stakeholders from different age groups and knowledge areas, with different level of work experience. Gender balance was also requested and it was recommended that some of the stakeholders had experience working with people with disabilities (cognitive and physical).

The recruitment process of the learners and stakeholders invited to attend to the Helsinki co-design event varied from institution to institution. In some cases, practice partners organised a contest to select learners based on a motivation essay. Other practice partners invited learners and stakeholders they knew through their participation in past activities or ongoing ones. Information about the invitation strategies was shared between practice partners. When necessary, specific recommendations were provided based on the particularities of each institution.

To make sure that the project partners (and through them the learners and the stakeholders) had similar understandings and expectations regarding the co-design event, the Aalto team organised online meetings to inform partners about the aims and the structure of the meeting, as well as the recruitment of learners and stakeholders. Having a fluid communication with the participants was considered necessary to involve them from the very beginning and ensure that their specific needs and concerns were taken into consideration. In addition to the online communication, information materials about the travel arrangements, the co-design approach, as well as the agenda of the event were shared before the meeting in Helsinki.

3.3.3 Facilitation

The facilitation team was formed by six researchers from the Learning Environments research group of Aalto University. Most of them were familiar with science learning outside the classroom and had experience organising and facilitating participatory and co-design workshops in diversity of contexts connected to learning and education. Each facilitator was assigned to a specific theme group. A facilitation guide book was created to prepare the co-design event and ensure the smooth coordination of the facilitation team.

In the Helsinki co-design event, the facilitators’ role was to ensure that the participants felt free to express themselves and participate in the co-design activities. While active participation of the attendants is key in co-design events, as facilitators, we considered important to enable participants to contribute in different ways. Thus, the facilitation work focused on ensuring that everyone had the opportunity to participate in a meaningful way, rather than pushing participants to adopt a proactive and leading attitude.

The creation of a friendly atmosphere, in which the participants feel comfortable to speak their mind and be creative without fear of being judged is also important for the success of a co-design session. For this reason, special attention was paid to ice breaking activities. These activities were meant to help participants know each other while setting a friendly, relaxed atmosphere. Considering the big size of the group, we decided to have two short icebreakers, one in which all the co-design event attendants participated, and another one for the members of each of the theme groups. The icebreaker for the whole group consisted in a name game with a throwable microphone. The icebreaker for the members of the theme groups consisted in short interviews between pairs of the same theme group. Each member of a theme group filled another peer's badge and introduce the person to the other members of the same theme group.

In the Helsinki co-design event, the participants were distributed in three working groups, each of them focused on a particular theme: inclusion, engagement, or assessment and recognition of learning. At the beginning of the event, participants were invited to select the theme of their interest by picking a badge[13]. While the theme groups were stable throughout the co-design event, they were subdivided in different ways depending on the activity that the participants were asked to perform (see table 5). The variation of the group sizes was used as a strategy to support different type of interactions (in smaller, medium and bigger groups) and ensure that everyone had the opportunity to participate (see figure 2).

Table 5. Distribution of the groups for each of the Helsinki co-design event activities

Activity	**Group size and number of groups**
Picking badges and making groups	The whole group of 49 participants was divided in three theme groups (each of the theme groups was formed by 18-17 people)
Concept mapping	Each theme group was divided in two subgroups. In total there were six groups of eight to nine people each building the concept maps.
Consolidating the concepts maps	The concept maps were shared and discussed in each of the theme groups. In total, there were three groups of 18-17 people each.
Framing of challenges and opportunities	Each theme group was divided in two subgroups. In total there were six groups of eight to nine people each.
Consolidating the challenges and opportunities	The challenges and opportunities were shared and discussed in each of the theme groups. In total, there were three groups of 18-17 people each.
Prioritization of the unified opportunities	Individual activity performed by each of the members of the theme groups. Each group was formed by 18-17 people.
Averaging the prioritization scores	This task was performed by the members of each of the theme groups. In total, there were three theme groups, each of them was formed by 18-17 people.
Sharing session on the challenges and opportunities identified for each of the themes	The sharing session took place with the whole group, which was formed by 49 people.

[13] In order to ensure that the theme groups were balanced, there was a limited number of badges associated to each of the themes.

Ideating design solutions	Each theme group was divided in four groups, each of them formed by four to five people. In total there were 12 groups creating design solutions.
Assessing the design solutions	Each ideation group assessed the design solution of another group working on the same theme. There were four groups per theme. In total, this activity was performed by 12 groups.
Iterating the design solutions	Each of the ideation groups was reduced to three to four people (the missing member joined a separate group focused on the final presentations). In total, 12 groups of three to four people each iterated the design solutions based on the feedback received.
Preparing the final presentations	One member from each of the ideation groups joined a separate group for preparing a presentation summarising the work conducted around a specific theme. In total, there were three groups of four people working on the final presentations.
Sharing session for presenting the work around each of the themes	Representatives of each of the theme groups presented their work to the whole group, which was formed by 49 people. Five stakeholders from the Finnish context attended the final sharing session.

Figure 2. Images[14] of the working groups Helsinki co-design event.

[14] Participants to the Helsinki co-design event were asked for permission to use their images in the SySTEM 2020 research and dissemination materials.

The Helsinki co-design event included several sessions for sharing the work and discussions that happened inside the teams. In order to speed up and set a dynamic rhythm, the facilitators asked each of the groups to define a spokesperson to present their work (see figure 3).

Figure 3. Images of the sharing sessions that took place during the Helsinki co-design event.

3.3.4 Co-design methods and materials to support participation

The Helsinki co-design event aimed to help gain understanding, as well as to define and ideate solutions around inclusion, engagement, as well as assessment and recognition of science learning outside the classroom. To support the participants to build shared understanding, as well as to define and ideate solutions, the activities proposed in the co-design event drew from design thinking methods (Brown, 2008) (see table 6). In particular, the methods adopted in the Helsinki co-design event focused on understanding and defining consisted of concept mapping, framing challenges and opportunities, card sorting, clustering and prioritization. Once the participants had defined the theme and selected a specific opportunity, they started to ideate solutions. The methods used to support the ideation process consisted of brainstorming and sketching. Below, we describe each of the methods used during the Helsinki co-design event.

Concept mapping: Participants were asked to build a conceptual map about their group theme (inclusion, engagement, or assessment and recognition). They had freedom about the elements to include in the map and how to represent the concepts (for instance, through text and/or visuals). The purpose of this activity was to open a conversation inside the groups and foster them to build a shared understanding on the topic based on their experiences in science education and learning outside the classroom. In order to encourage free expression, the participants were encouraged to write their first thought on the topic on post-it notes. After this individual task, the group started clustering and filtering the similar concepts and identifying the diverse interrelations. The process of clustering and filtering was repeated twice as the participants started developing the concept maps in smaller groups and then merged their maps with the ones built by the other groups working on the same theme. Having two groups focused on the same theme was considered crucial for mapping a wider range of concepts and identifying the key ones based on how recurrent they were. The consolidated concept maps about each of the themes were hanged in the walls of the room in order to make them visible for all the participants throughout the co-design event sessions (see figure 4).

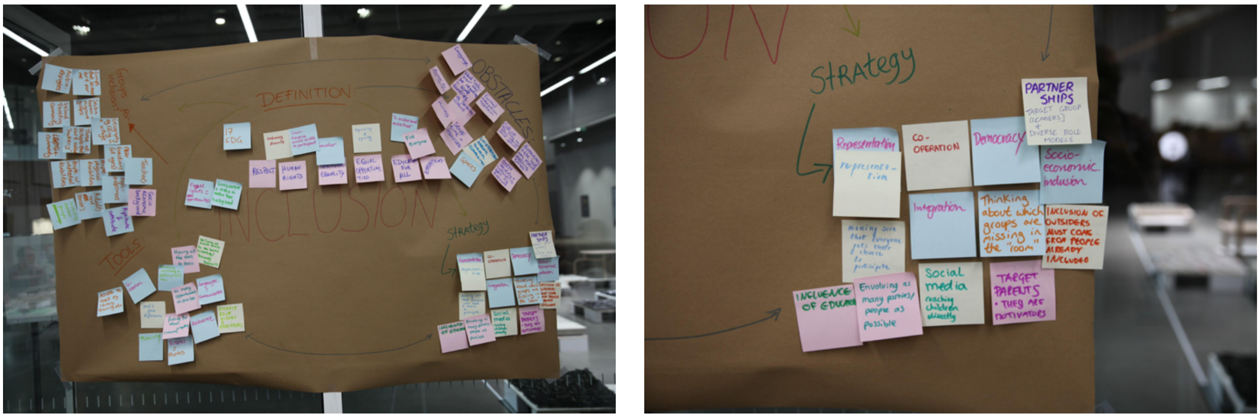


Figure 4. Consolidated concept map about inclusion in science education outside the classroom.

Framing of challenges and opportunities: The participants were invited to think about the challenges and opportunities connected to the specific theme (inclusion, engagement or assessment and recognition of learning) around which they had built their concept maps. The supporting materials for this task were the How Might We Triggers and a selection of proto-personas that the Aalto team had built based on the insights gained during the contextual inquiry (see table 6 for a description of these materials). The participants were encouraged to go through the cards and sort them according to the questions they considered to be more relevant (see figure 5). The participants were encouraged to not to restrict their thinking to the issues raised in the cards and think about other relevant aspects that might be missing. This activity was intended to support more elaborated discussions about specific aspects that were considered key in each of the co-design event themes. Similar to the previous activity, two different groups worked on the challenges and opportunities related to a specific theme. Once each of the groups had framed the challenges and opportunities around a specific theme, their work was shared and merged with the other group’s work about the same theme.

Figure 5. Images of the How Might We trigger cards and the proto-personas used when framing the challenges and opportunities connected to each of the co-design event themes.

Prioritization of unified opportunities: After consolidating the challenges and opportunities around a specific theme, each person working on a particular theme was asked to value the priority level of each of the opportunities based on how high or low might be their impact and how difficult or easy might be their implementation. Each participant received a value matrix to document their assessments (see figure 6).

Averaging prioritization scores: The priority values assigned to each of the opportunities associated with a specific theme were averaged. This way, it was possible to identify the opportunities with the highest priority for each of the themes. In order to document the process, a score canvas was given for each of the themes (see figure 6).

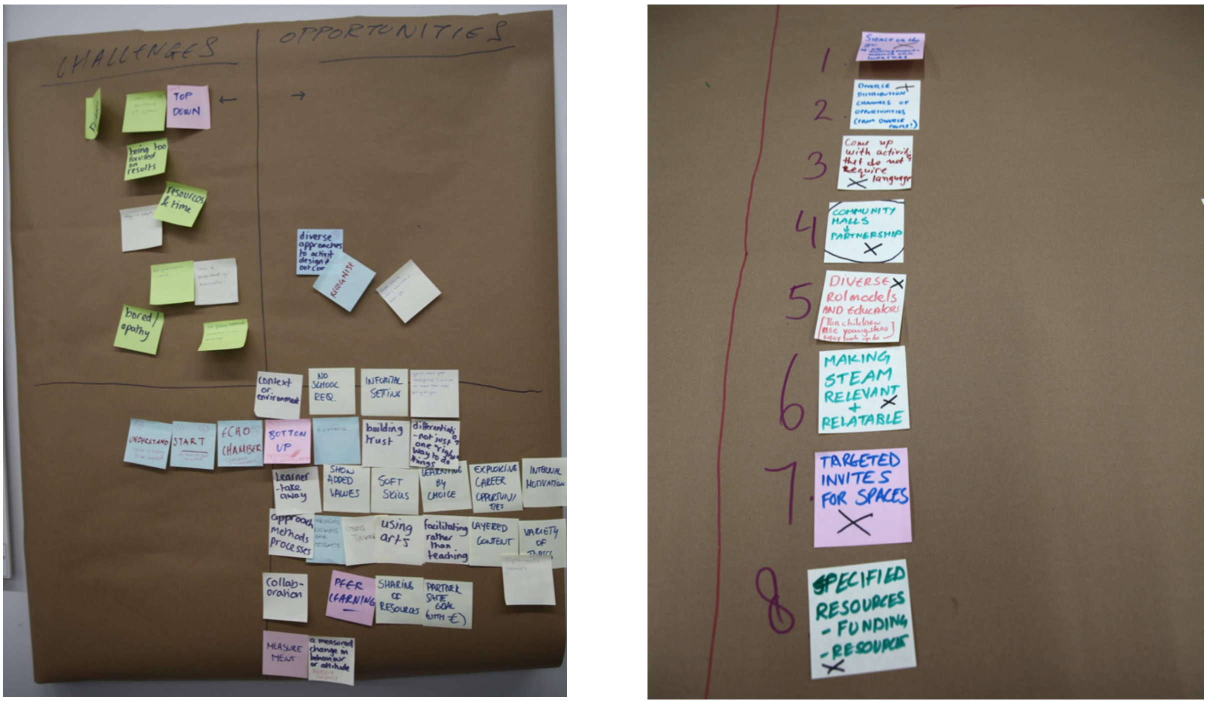


Figure 6. Framing of the challenges and opportunities and selection of opportunities performed by one of the co-design event groups.

Ideation: Each of the theme group members selected one of the four highest priority opportunities they wanted to develop further. Once the groups were formed, they were asked to perform a creativity technique called the Crazy Eights consisting in sketching eight different design ideas around a specific opportunity in eight minutes (see figure 7). The fast pace of this brainstorming technique aimed to help participants adopt a creative mindset and expand the design opportunity space. After the eight minutes, the people working around the same opportunity voted the ideas sketched in the Crazy Eights that they considered most promising. The ideas most voted were used to define a design solution. In order to support the further elaboration of the design solutions, each of the groups received a design solution canvas (see figure 7).

Figure 7. Images of the participants' ideas produced with the Crazy Eights technique and the design solutions drafted in the design solution canvas.

The design solutions were assessed by another group working on a different design opportunity connected to the same theme. Each of the groups received some guidelines specifying the criteria for assessing the utility, viability and feasibility of the design solutions. The feedback was provided by commenting on the design solution canvas. Based on the feedback received, each of the groups iterated their design solutions before pitching their ideas in the final sharing session of the co-design event.

Table 6. The methods and materials used during the Helsinki co-design event in relation to their purpose.

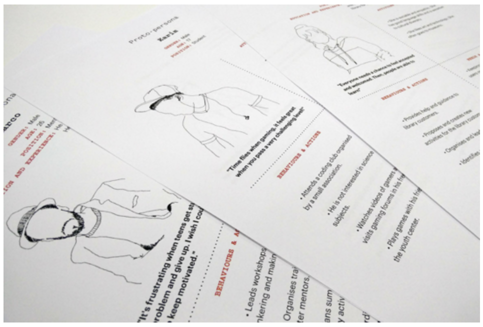
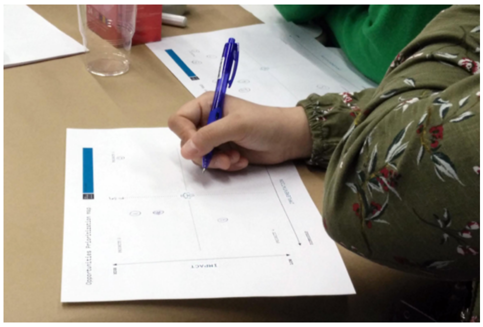
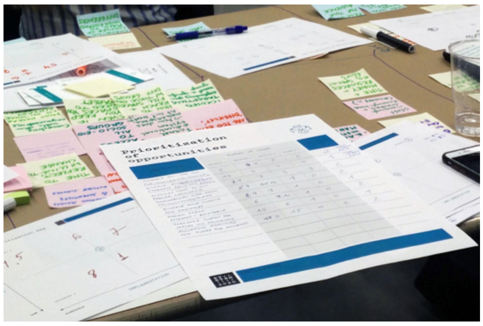
Method	Purpose	Materials
Concept mapping	Understanding and defining	A slide showcase of the co-design event themes was projected as background information. Paper, post-its, markers.
Framing of challenges and opportunities	Understanding and defining	How Might We trigger cards, proto-personas. Paper, post-its, markers.
Prioritization of the unified opportunities	Understanding and defining	Prioritization of the opportunities I (individual score map). Pens.
Averaging the prioritization scores	Understanding and defining	Prioritization of the opportunities II (canvas with group averages). Pens.
Ideation of design solutions	Ideating	Design solution canvas, guidelines for assessing the design solutions. Papers, post-its, pens, color dot stickers.

The materials used during the co-design event were specifically designed based on the results of the contextual inquiry and the specific needs of the SySTEM 2020 project. The project members from the related WPs (in particular, WP3 and WP5) were invited to comment and give feedback during the elaboration of the co-design event materials. The materials design followed the visual identity guidelines of the SySTEM 2020. In particular, the project visuals and colours were used in the materials of the Helsinki co-design event to support the distribution of participants in different groups. In table 7, we describe the materials designed for the Helsinki co-design event.

Table 7. The materials used during the Helsinki co-design event.

Materials	Description	Image
Badges	Identification cards for the co-design event participants. The badges indicated the theme group (inclusion, engagement or assessment and recognition of learning) and included a QR code for accessing the co-design event materials available online. Same theme badges included a slightly different image of a robot. These images were used for group-making. The badges included empty fields about participants' personal information[15].	
Slideshow of the co-design session themes	Inspiration texts and images related to the co-design event themes (inclusion, engagement, assessment and recognition of learning). The slides were projected as background material during the concept mapping activity.	
How Might We trigger cards	Inspiration cards with questions identifying several challenges connected to the co-design event themes. The challenges were based on the findings from the contextual inquiry conducted before the event. There were three decks of cards, each of them with specific questions for each of the co-design event themes (see the appendix 4). Each of the decks contained 18 cards (some of the cards were left empty in order to encourage participants to note down missing issues).	

[15] See the subsection about facilitation for a further description on the use of the badges in the groups-making and in the icebreaking activities.

Proto-personas	Based on the findings from the contextual inquiry, six proto-personas[16] describing diverse fictional characters connected to science learning outside the classroom in different contexts were created. The proto-personas included information about attitudes and interests, behaviors and actions, and needs and pain points that can be frequently found in science learning outside the classroom.	
Prioritization of the opportunities I (individual score map)	A value matrix that assigns different priority levels in a scale from one to four, based on the expected impact (high or low) and the readiness to implement (easy or difficult) a solution for a specific opportunity. Each participant was expected to individually assess the consolidated opportunities related to a specific theme with this value matrix.	
Prioritization of the opportunities II (canvas with group averages)	This document aimed to support the averaging of the priority values set for the consolidated opportunities of a specific theme. Documenting the prioritization of opportunities at the group level was key for keeping track of the group's decisions and ensuring a smooth connection with the next task, which was scheduled for the following day.	
Design solution canvas	The design solution canvas was created as a tool to help participants structure the design solutions. It specified different aspects to take into consideration when creating a solution.	

[16] Despite the proto-personas being based on empirical data, we use the term "proto-persona" since they have not undergone through a validation process.

Guidelines for assessing the design solutions	Having shared criteria for assessing the design solutions was considered critical for achieving acceptable levels of quality. To this purpose, the groups were given guidelines for assessing the design solutions. The guidelines included criteria to assess the utility, viability and feasibility of the design solution.	

In order to support and document the groups' work during the co-design event, participants were asked to report their work by filling digital templates. The templates consisted in slides for reporting about the consolidated challenges and opportunities for each of the themes, the iterated versions of the design solutions and to summarise all the work conducted under a specific theme. The templates and additional materials regarding the event were available online in the DesignIT platform.

The DesignIT platform (designit.e-ce.uth.gr) was used for documenting the co-design process. Each theme had its own space upload, in which participants could document and organise their drafts, intermediate outputs and final presentations (see figure 8).

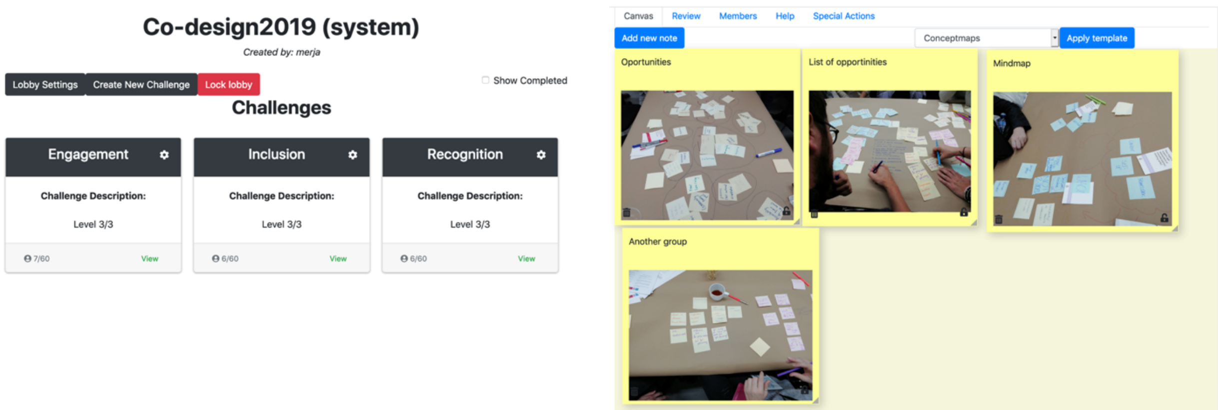


Figure 8. The Image in the left displays the space of each theme. Inside the third one "recognition" the documentation of the concept mapping process is presented.

The DesignIT platform has been designed in an Erasmus+ project called DesignIT. The aim of the platform is to support documentation of the contextual inquiry investigations and various workshop styles and design methods. DesignIT has been designed to work both on desktop and mobile platforms. Using DesignIT In the Helsinki co-design event was optional. Thus, the participants were able to choose between using the DesignIT platform[17] or another online service.

[17] At the beginning of the event, the organisers introduced the tools and the participants who were interested in using the DesignIT platform were asked to sign a consent form.

4 Outputs and outcomes from the SySTEM 2020 co-design

4.1 Co-design outputs

The outputs of the Helsinki co-design event consist of the design solutions (n=12) created during the ideation session as they capture the participants' thinking on the opportunities and challenges connected to inclusion, engagement, and assessment and recognition of science learning outside the classroom. The design solutions are products and services that connect to the challenges and opportunities that the participants considered important to address as they could have a high impact and were considered easy to implement. Although the participants focused on the opportunities that received the highest priority, the other opportunities were also viewed as relevant. In table 8, we list the design solutions created by the co-design event participants around inclusion, engagement, as well as assessment and recognition.

Table 8. List of the design solutions created for each of the Helsinki co-design events themes.

Theme	**Design solution**
Inclusion	"Improve your life" workshop network
	Implementation of diverse distribution channels through connections
	Local Engagement Committee
	Guardians of Inclusion
Engagement	LocalLearnLink
	Fail-safe: a Festival Celebrating Failure
	Inquiry-based Learning
	Kitchen as a Lab
Assessment and recognition	Free Day! – Your Way!
	MILA – My Informal Learning Accomplishments
	3 Step Method
	License to Fail

4.1.1 Outputs about inclusion

The design solutions created around the theme of inclusion focused on the opportunities connected to a) Making STEAM relatable and relevant, b) Supporting diverse distribution channels, c) Diverse role models and educators and d) Collaboration between different actors and entities. In table 9, we provide a list of the consolidated prioritization of opportunities about inclusion.

Table 9. Prioritization of the opportunities to support inclusion in science learning outside the classroom

Opportunities to support inclusion in science learning outside the classroom	**Priority level**
Diverse distribution channels (from diverse people, social media, library, schools)	1
Diverse role models and educators	1
Targeted invites for spaces on programs	1
Science on the go (using Virtual Reality, moving events, and through Internet)	2
Activities that do not require language	2
Partnerships with local organisations/places	2
Making STEAM relevant and relatable	2
Allocating resources and money for inclusion	2

At the co-design sessions, the participants were asked to consider the positive changes that their solutions were expected to bring. The design solutions focused on supporting inclusion in science learning outside the classroom aimed to increase people's science capital, encourage innovation within communities, make science approachable and valuable in everyday life, take advantage of available resources and show the diversity of groups, institutions and activities connected to STEAM (see table 10 for a further description of the design solutions and their goals).

Table 10. Description of the design solutions and their challenges focused on inclusion.

Design solution	**Description**	**Goals**
"Improve your life" workshop network	A series of regularly scheduled, free workshops open to everyone. The workshops have a hands-on, experience-based format. People can join the workshops and contribute as participants or organisers. These workshops are expected to take	- Making STEAM more relatable and relevant. - Reaching a diverse and inclusive demographic.

	place within a target community where locals gather to face challenges together and find solutions using the existing resources and spaces. This network of workshops aims to include permanent activities, but also implement temporary ones. In order to include participants with diverse backgrounds and sociodemographic factors, it is key to engage diverse role models and trainers and use diverse campaign strategies to advertise the workshops.	- Making STEAM accessible to everyone.
Implementation of diverse distribution channels through connections	Supporting networking and making connections among diverse organizations, institutions and individuals through continuous activities that promote STEAM. In order to foster the target groups to make connections and bridge information, knowledge and resources, it is important to organize different type of activities and events. It is also important that the events promoted within the organizations are led by people who are role models inside the organizations.	- Reaching diverse groups. - Showing the different organizations relevance and the benefits of making diverse type of connections. - Making science relevant and relatable.
Local Engagement Committee	Creation of a public engagement committee dedicated to scientific outreach within the local community. This solution aims to support the identification of diverse role models and educators at local level (if successful, the solution would gradually scale to wider contexts). The local engagement committee focuses on reaching minority groups in STEAM, in particular those who feel that science is alien to them, as well as educators who face difficulties to support inclusion in their professional practice.	- Helping communities and local minorities engage with STEAM. - Providing educators opportunities to reflect on their work and share knowledge. - Fostering a diverse community of people engaged in STEAM.
Guardians of Inclusion	This solution seeks to enhance the learners' informal learning ecosystem through their guardians. In particular, especial attention is dedicated to involve the guardians of minority groups in STEM and STEAM programmes like girls, young people from disadvantaged communities, as well as young people with disabilities. Increasing the guardians' involvement is considered key for giving them a sense of ownership and better understand the benefits that STEAM might have for their children. The expected result of the actions performed to increase the guardians' awareness and knowledge on STEAM is to make them more willing to encourage their kids to take part in STEAM programmes. In order to reach these target groups is important to develop awareness campaigns in the contexts that are most frequently visited like for instance, shopping malls, parks...etc.	- Increasing engagement and involvement of guardians in STEAM programmes - Rising the number of participants from minority groups in STEAM. - Raising awareness of the value of science and STEAM programmes.

4.1.2 Outputs about engagement

The SySTEM 2020 co-design solutions for supporting engagement in science learning outside the classroom addressed challenges related to involving people, relevance of the offerings for diverse groups and the lack of resources. Simultaneously, the solutions took advantage of the opportunities connected to the context and the chances for supporting collaboration at different levels and between different groups (see table 11 for a complete list of the consolidated opportunities identified at the co-design event).

Table 11. Prioritization of the opportunities to support engagement in science learning outside the classroom

Opportunities to support engagement in science learning outside the classroom	**Priority level**
Approach, methods and processes (facilitating not lecturing)	1
Measurement (validating alternative modes)	1
Context or environment (the environment as a third teacher)	1 - 2
Collaboration (all inclusive, cross-disciplinary, formal informal)	1 - 2
Bottom-up approach to activity design	2
Added Value (soft skills, Learner take-away)	2

The design solutions exploring the theme of engagement sought to improve science learning outside the classroom by making positive changes based on new and more exciting ways to teach, recognizing the value of informal and lifelong learning, supporting interrelations between formal and informal education, embracing failure, adopting bottom-up methods and fostering WOW-moments based on feelings of success and productivity. Table 12 describes the design solutions created at the Helsinki co-design event and their goals.

Table 12. Description of the design solutions and their challenges focused on engagement.

Design solution	**Description**	**Goals**
LocalLearnLink	Online Collaboration Platform to organize events and yearly meet-ups in formal and informal education environments. Linking formal and informal science education within the local environment offers the opportunity to recognize informal education in the formal system as well as enhancing formal education. Special emphasis is made on using local resources in order to identify and offer training on methods and topics connected to science learning.	- Offering a broad range of skills and methodologies to all parties. - Supporting connections and collaboration among practitioners involved in research, technology development and innovation. - Measuring and improving

		the quality of formal and informal science education.
Fail-safe: a Festival Celebrating Failure	Bottom-up approach to activity design and implementation, in which stories of failure are shared to inspire new modes of engagement through co-creation. The festival is a space that fosters experimentation and risk-taking in science learning projects through the adoption of co-creation methods. The opening of such space is expected to offer a safe environment where citizens and institutions active in STEAM can kick-start co-creation processes in science learning projects.	- Supporting the adoption of co-creation processes in science learning projects for goal-setting, defining procedures and outputs. - Fostering experimentation and risk-taking by recognizing the value of failure.
Inquiry-based Learning	A science learning method based on inquiry. The process is adaptable and can be used in a variety of activities as it is open-ended and focuses on processes rather than outcomes. It aims to trigger learners' interest and support the training of soft skills by fostering creative thinking and immersion. The methods stress the role of the workshop giver as a learning facilitator.	- Supporting science learning through inquiry processes. - Fostering learners' creativity and soft skills.
Kitchen as a Lab	Proposal for engaging parents and guardians with their children through science experiments to be conducted at home with low-cost and easily accessible resources. Kitchen as a lab seeks to open a joint space for guardians and children to explore, get inspired and experience trial & error in everyday contexts. The scientific experiments follow a playful approach that seeks to encourage curiosity and the adoption of an open-minded attitude among guardians and children.	- Engaging parents, guardians and kids as a learning unit. - Supporting Do It Yourself (DIY) science exploration and experiences in everyday contexts. - Fostering curiosity and an open-minded attitude towards science learning.

4.1.3 Outputs about assessment and recognition

The design solutions focused on supporting assessment and recognition aimed to expand the definitions and set of skills connected to science learning outside the classroom. While tackling challenges related to the lack of learners' involvement and their perceptions of schooling as meaningless and disconnected from their lives, the solutions seek to widen the scope of assessment by providing new tools and methods. Special attention was paid to finding solutions that could be potentially fun (see table 13).

Table 13. Prioritization of the opportunities to support assessment and recognition in science learning outside the classroom

Opportunities to support assessment and recognition in science learning outside the classroom	Priority level
Expand the definitions and set of skills	1
New tools	1
Potentially fun	1
The group as group and individual	2
Trans-organizational and cross-border collaboration	2
Improve organization	2
Impact policy including formal education and society	2
Ease of adoption that is non-domains specific	2

The solutions supported participation, equality, freedom, well-being in order to increase learners' and educators' awareness on their actions, encourage sharing and transferability of experiences. Table 14 presents a description of the design solutions created during the ideation session of the Helsinki co-design event.

Table 14. Description of the design solutions and their challenges focused on assessment and recognition.

Design solution	Description	Goals
Free Day! – Your Way!	Setting one school day to explore aspects connected to science that connect to students' personal interests. The solution is presented as a "free day" to stress the importance that learners have fun, get out of the school and engage in issues they are motivated to know more about. By encouraging learners to visit other contexts and spaces to work and learn about science concepts, it is expected that they make bridges between different contexts and the learnings that take place in them. This solution proposes diverse types of formative and summative assessment at the individual and group level. The purpose is to encourage learners to pay attention to their learning process and recognise the different ways in which they implement scientific knowledge in their personal projects.	- Supporting playful approaches to explore science concepts. - Advancing learners' skills to develop personal projects about science concepts. - Involving a diversity of actors and contexts in STEAM education.

MILA – My Informal Learning Accomplishments	Assessing learners' skills with badges. This solution focuses on supporting assessment in informal learning contexts like for instance, makerspaces and out-of-school activities. This solution presents three types of badges: 1) badges that learners fill by themselves, 2) badges that learners fill for other peers, and 3) badges filled by the institution. The MILA badges aim to help learners gain awareness on their learnings, as well as include different views in the assessment process. In addition, the different badges can be used to make a learning story, in which learners can share their achievements and experiences with others.	- Supporting different types of assessment. - Facilitating the recognition of learning. - Increasing learners' awareness on their learning achievements and experiences through learning stories.
3 Step Method	A method for assessing learning through spontaneous observation in non-formal and formal education environments. The method consists in three steps for guiding joint assessment between learners and educators. First, there is a two-way-feedback between learners and educators in which they share their views and impressions on the process and the final outcomes. Second, learners and educators step away. During this period, learners review their work independently. In order to encourage learners to find their own solutions, educators provide little guidance or instructions during this step. Third, learners and educators repeat the step one which consists in the two-way-feedback, this time of the iterated work. The learners might review again their work, if considered necessary.	- Supporting comprehensive assessment. - Adopting a participatory approach to assessment. - Fostering learner's active involvement and their critical thinking skills.
License to Fail	Supporting the recognition and value of failure in the learning process through a service and tools. Learners are encouraged to be creative, experiment and take risks that might eventually lead to failure. In order to leverage the opportunities that failure brings for gaining deeper understanding, people need to learn how to recover from it. This solution includes a License plate "License to Fail" and a set of cards that help explaining how to fail better. These tools are meant to be used in workshops or similar type of events in which people get familiar to the concept, the tools and how to guide and recovery from failure. Failing, coping and growing are considered as stages of assessment, which are based on self and peer-assessment. The service and the tools are intended to be primarily used in informal and non-formal education.	- Helping learners experience failure in a positive way. - Encouraging learners to practice failing and find ways to recover from it. - Providing strategies and tools to cope with failure and learn from it.

4.2 Co-design outcomes

The SySTEM 2020 co-design outcomes consist in the insights gained through the analysis of the outputs generated at the Helsinki co-design session. We conducted a thematic analysis of the topics and issues most frequently discussed during the co-design sessions. In particular, special attention was paid to the similarities among the design solutions for each of the themes in order to identify the underlying ideas that permeated participants' understanding and thinking about possible directions to improve inclusion, engagement, as well as the assessment and recognition of science learning outside the classroom.

4.2.1 Outcomes on inclusion

The design solutions created during the Helsinki co-design event built from the local level and played special attention to the contexts and challenges faced by diverse communities. Supporting networking among local players was considered important for developing a tight science learning network that offered learners diverse entry points.

The suggested mode of operating was to start small and gradually scale the solutions and practices that worked best. To a large extent, the solutions rely on people's enthusiasm to take them forward. In this regard, the adoption of a grassroots approach was expected to support high levels of engagement and ownership.

All the solutions focused on making STEAM relevant and relatable. To this purpose, it was necessary to expand the definition of science and visualize the diversity of approaches, ways of doing and being involved that coexist inside science, STEM and STEAM. Giving voice to diverse role models and influencers was suggested as one way to capture children and youngsters' attention and challenge their assumptions towards science. Table 15 and figure 9 offer an overview of the design solutions focused on inclusion by describing them through keywords and through a tag cloud.

Table 15. Keywords describing the design solutions focused on inclusion in science learning outside the classroom.

Theme	Design solution	Keywords
Inclusion	"Improve your life" workshop network	Local resources and contexts, local challenges, diversity, role models, self-organization, network, community, workshops, making science relatable and relevant
	Implementation of diverse distribution channels through connections	Networking, role models, diverse target groups, making science approachable, events, distribution channels
	Local Engagement Committee	Outreach, local community, minorities, role models, expand involvement, making science approachable and connected to everyday life

	Guardians of Inclusion	Guardians' involvement, campaigning, making science approachable and relevant, ownership, local contexts

Figure 9. Tag cloud of the text descriptions and keywords of the design solutions for supporting inclusion in science learning outside the classroom.

Based on the outputs of the Helsinki co-design event, we summarise the following recommendations to guide further designs exploring how to support inclusion in science learning outside the classroom:

- Build from people's interests and experiences in order to increase their science capital.
- Use participatory approaches in order to support active involvement and ownership.
- Understand how different groups perceive science in order to define how to expand their views and challenge stereotypes.
- Start with small initiatives at the local context before aiming to scale.
- Involve social actors, as well as indirect stakeholders such as parents and guardians.
- Identify spaces that work (or can work) as public spaces for science learning.
- Embrace diversity. Support diverse type of activities, focused on diverse topics and disciplines, materials, role models and learners who participate.
- Support multiple connections in order to create a network of events and resources for science learning outside the classroom.

4.2.2 Outcomes on engagement

Based on the discussions and reflections around engagement in science learning outside the classroom, the participants of the Helsinki co-design event proposed a definition of engagement. In their words, engagement is "learning through continued participation in a variety of activities which are relevant, fun, interesting and rewarding to the person in question, and sharing any element of the experience". We consider this definition is a relevant outcome of the session as it is the result of a group reflection process that led to a shared understanding on the concept of engagement.

The design solutions explored engagement in science learning outside the classroom from the perspective of the organizations and institutions, the educators and facilitators, as well as the learners and their parents and guardians. In the co-design sessions, the participants acknowledged the potential of data tracking for gaining awareness and support engagement. There was consensus that tracking should be integrated in the activity design as part of inquiry-based learning processes, although it was not clear what aspects would be more relevant to track. The participants rejected using the data collected to support external evaluations of the learners' activity.

The solutions created during the co-design event shared a participatory approach with strong emphasis on collaboration, stressed the importance of easy access to science learning activities, spaces and resources, and highlighted the need to support open-ended processes that enable participants to co-create, experiment and take risks (see table 16 and figure 10).

Table 16. Keywords describing the design solutions focused on engagement in science learning outside the classroom.

Theme	**Design solution**	**Keywords**
Engagement	Online Collaboration Platform	Collaboration between formal-informal, local, knowledge transfer, sharing, recognition of achievements
Engagement	Fail-safe: a Festival Celebrating Failure	Co-creation, experimentation, risk-taking, sharing, creativity, empowerment
Engagement	Inquiry-based Learning	Active learning strategies, creativity, learning design, soft-skills, motivation
Engagement	Kitchen as a Lab	Engaging parents and kids, experimentation, learning resources, sharing, DIY attitude

Figure 10. Tag cloud of the text descriptions and keywords of the design solutions for supporting engagement in science learning outside the classroom.

By understanding science learning as engagement with scientific practices, ensuring that people have opportunities to participate in science learning in multiple occasions becomes crucial. Below, we list several recommendations for supporting engagement in science learning outside the classroom based on the outputs from the co-design event that took place in Helsinki:

- Support exploration, experimentation, and risk-taking.
- Adopt and foster a DIY attitude.
- Trigger curiosity and creativity. Pay also attention to the soft-skills that play a role in collaboration.
- Connect science learnings that happen in formal and informal learning environments located in the neighbourhood. Foster collaboration and co-creation among actors of diverse contexts.
- Create opportunities for joint involvement between parents, guardians and children.
- Make science relevant by showing its value in everyday situations.
- Support learners' self-confidence. Help them recognize their achievements and advance their skills from their own level.

4.2.3 Outcomes on assessment and recognition

The proposed solutions at Helsinki co-design event to improve assessment and recognition of science learning heavily drew on self-assessment, self-improvement, creativity and a fluid approach to evaluation. According to the participants, the focus should be on supporting different types of assessment that place the emphasis on the process, rather than on performing quantitative measuring and summative evaluations.

Similar to the design solutions and discussions around inclusion and engagement in science learning, the participants exploring assessment and recognition of science learning outside the classroom acknowledged the value of making connections between formal and informal learning, the adoption of participatory approaches, as well as the need to support risk-taking and learn from failure (see table 17 and figure 11 for a description of the design solutions focused on assessment and recognition through keywords and a tag cloud).

Table 17. Keywords describing the design solutions focused on assessment and recognition in science learning outside the classroom.

Theme	Design solution	Keywords
Assessment and recognition	Free Day! – Your Way!	Connecting formal-informal learning, assessment, teachers training, learning strategies, toolkit, sharing, co-design
Assessment and recognition	MILA – My Informal Learning Accomplishments	Informal learning assessment, badges, storytelling, peer assessment, self-assessment, recognition, sharing, transfer, awareness
Assessment and recognition	3 Step Method	Assessment method, participatory, learners' involvement
Assessment and recognition	License to Fail	Risk-taking, creativity, failure, learning strategies, learning design, recognition, self-assessment, peer-assessment

Figure 11. Tag cloud of the text descriptions and keywords of the design solutions for supporting assessment and recognition in science learning outside the classroom.

Based on the analysis of the outputs generated during the Helsinki co-design event, we make several recommendations for supporting assessment and recognition of science learning outside the classroom:

- Adopt a learner-centred approach to assessment in which learners are actively involved.
- Support diverse types of assessment (self and peer-assessment) throughout the learning process.
- Use assessment as a tool to increase learners' awareness on diverse competences, with particular attention to transversal competences that can be transferable to other contexts.
- Focus on learning strategies that approach self-assessment from perspectives traditionally not appreciated in formal education like failure and free experimentation.
- Recognise learners' achievements in diverse and creative ways.
- Consider assessment and recognition as opportunities to give and receive constructive feedback.

4.3 Summary

Although each of the Helsinki co-design event working groups was focused on a specific theme, many of the issues, as well as the opportunities for action raised by the participants of the different theme groups were closely related.

In this section we present a summary of the shared aspects among the opportunities and design solutions about inclusion, engagement and assessment and recognition of science learning discussed created during the Helsinki co-design event:

Embracing diversity: Supporting diversity was an important aspect discussed by all the theme groups. Recognizing and supporting diversity in science learning works at different levels, which range from the different ways of understanding “science”, to the contexts where science learning happens, the backgrounds of the people involved in science and the ways to participate and get involved in activities connected to science.

Adopting participatory approaches: Based on the participants’ discussions and the design solutions created during the co-design event, learners’ and communities’ active participation is a valuable strategy for supporting high levels of involvement. From this perspective, learners’ and communities’ participation is connected to the relevance and sustainability of the solutions for supporting science learning outside the classroom.

Leveraging readily available resources: While some design solutions stressed the value of the local initiatives, others advocated for starting small and joining forces with existing resources (in terms of people, spaces and equipment) and others stressed the value of DIY approaches with low-cost and easy-to-find materials. We consider that participants shared an interest in taking advantage of what is already accessible and that can have an impact in the short-middle term. Although the guidelines for selecting the design opportunities prioritized the ones that could have high impact in the short-term, we consider that participants’ emphasis on starting small and gradually scale the solutions reflected a concern for the sustainability of the design solutions.

Building connections between formal and informal science learning: Several design solutions advocated for building networks between diverse actors and environments connected to science learning. Merging science formal education with non-formal and informal learning is an ongoing trend that the participants of the Helsinki co-design event were willing to take further. Simultaneously, there was a concern for avoiding formalizing informal and non-formal learning. Perhaps for this reason, several design solutions stressed the importance of supporting fun, free activities, based on learners’ interests. In the case of solutions focused on supporting assessment and recognition of science learning outside the classroom there was a strong emphasis on supporting learner-cantered and formative approaches to assessment, which differ from traditional evaluation methods used on formal education.

Fostering risk-taking and learning from failure: Several design solutions for supporting engagement, as well as assessment and recognition of science learning outside the classroom advocated for encouraging learners to explore and experiment, which might eventually lead to unexpected results failing to meet the intended goals. In turn, the participants' design solutions focused on supporting inclusion claimed for taking into consideration learners’ experiences and use them as an opportunity to trigger curiosity and learning. Although phrased in different ways, we consider that these design solutions emphasize the value of experiential learning in science learning outside the classroom.

Supporting transversal competences: Many of the design solutions argued for the need to avoid narrow visions of science, in which the learnings that take place in science contexts do not relate to other situations that are close to the learners' everyday experiences. Thus, skills connected to for instance, creative thinking, collaboration and communication were considered important for supporting a wider understanding of the different ways to engage in STEM and STEAM.

Acknowledging learners' achievements: The recognition of learning is an important element that can work at different levels. On one hand it creates opportunities for advancing education and for finding a job. On the other, acknowledging learners' achievements can be used as a tool to create awareness, support motivation and foster learners' self-confidence on their ability to undertake more ambitious challenges.

The commonalities between the opportunities and design solutions created around the themes of inclusion, engagement, as well as assessment and recognition of science learning outside the classroom is an interesting finding from the Helsinki co-design event as it helps define solutions that may simultaneously tackle aspects connected to the different themes.

5 Further work

The outputs and outcomes of the Helsinki co-design event are expected to influence further work in WP4 (D 4.2 and D 4.3), as well as in WP3 (task 3.6) and WP5 (tasks 5.1, 5.2 and 5.3). In particular, next actions in WP4 focus on the elaboration of a toolkit of design principles and methodologies for supporting science learning in non-formal and informal settings, including brokering further science learning opportunities (D 4.2). This deliverable builds on the findings from the contextual inquiry, as well as on the outputs and outcomes from the Helsinki co-design event[18]. The data collected about inclusion during the contextual inquiry, as well as during the Helsinki co-design event would be also taken into consideration in the elaboration of the white paper on equity-focused science education outside the classroom (D 4.3).

In addition, based on the participants' positive feedback on the co-design event materials, we plan to release these materials so other organisations and educators involved in science learning outside the classroom (but not connected to the SySTEM 2020) can use them to trigger discussions and generate ideas and solutions to support science learning outside the classroom.

We consider that the insights gained from the Helsinki co-design event are a valuable contribution for supporting science learning outside the classroom, and for adopting co-creation and co-design approaches to design science learning in non-formal and informal environments. Thus, this report would be used to inform dissemination actions through conference and journal papers.

[18] Considering the close connection between D 4.2 and D 5.5, the design of both deliverables would be coordinated in order to ensure a smooth transition between them.

References

Achiam, M., & Holmegaard, H. T. (2015). Criteria for gender inclusion. Hypatia Deliverable, 2.

Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). “Science capital”: A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, 52(7), 922-948.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). “Doing” science versus “being” a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, 94(4), 617-639.

Beyer, H., & Holtzblatt, K. (1998). *Contextual inquiry. Defining customer-centered systems*. San Francisco, CA: Morgan Kaufmann Publishers.

Blomberg, J., Giacomi, J., Mosher, A., & Swenton-Wall, P. (2017). Ethnographic field methods and their relation to design. In *Participatory Design* (pp. 123-155). CRC Press.

Bonsignore, E., Ahn, J., Clegg, T., Guha, M. L., Yip, J., Druin, A., & Hourcade, J. P. (2013). Embedding participatory design into designs for learning: An untapped interdisciplinary resource. In *Proceedings of the Tenth International Conference on Computer Supported Collaborative Learning* (Vol. 13).

Brown, T. (2008). *Design thinking*. Harvard Business Review, 86(6), 84.

David, S., Sabiescu, A. G., & Cantoni, L. (2013). Co-design with communities. A reflection on the literature. In *Proceedings of the 7th International Development Informatics Association Conference* (pp. 152-166). Pretoria, South Africa: IDIA.

Détienne, F., Baker, M., & Burkhardt, J. M. (2012). Quality of collaboration in design meetings: methodological reflexions. *CoDesign*, 8(4), 247-261.

Ehn, P. (2017). Scandinavian design: On participation and skill. In *Participatory Design* (pp. 41-77). CRC Press.

Howard, Z., & Melles, G. (2011). Beyond designing: roles of the designer in complex design projects. In *Proceedings of the 23rd Australian Computer-Human Interaction Conference* (pp. 152-155). ACM.

Hughes, J., King, V., Rodden, T., & Andersen, H. (1995). The role of ethnography in interactive systems design. *Interactions*, 2(2), 56-65.

King, S., Conley, M., Latimer, B., & Ferrari, D. (1989). *Co-design: A process of design participation*. Van Nostrand Reinhold Company.

Kolko, J. (2007). Information architecture and design strategy: The importance of synthesis during the process of design. In *Industrial Designers Society of America Conf*.

Kolko, J. (2010). Abductive thinking and sensemaking: The drivers of design synthesis. *Design Issues*, 26(1), 15-28.

Leinonen, T., Toikkanen, T., & Silfvast, K. (2008). Software as hypothesis: research-based design methodology. In *Proceedings of the Tenth Anniversary Conference on Participatory Design* (pp. 61-70). Indiana University.

Luck, R. (2003). Dialogue in participatory design. *Design Studies*, 24(6), 523-535.

van der Lugt, R., Bakkeren, M., & De Lille, C. (2009). *Co-design in a Pressure Cooker*. The Netherlands: Kenniscentrum Natuur & Techniek.

Maldonado, H., & Pea, R. D. (2010). LET's GO! to the Creek: Co-design of water quality inquiry using mobile science collaboratories. In *2010 6th IEEE International Conference on Wireless, Mobile, and Ubiquitous Technologies in Education* (pp. 81-87). IEEE.

Mattelmäki, T., & Visser, F. S. (2011). Lost in Co-X: Interpretations of Co-design and Co-creation. In *4th World Conference on Design Research*. Delft, The Netherlands.

Marttila, S., & Botero, A. (2013). The 'Openness Turn' in co-design. From usability, sociability and designability towards openness. In: Smeds & Irrmann (Eds.), *CO-CREATE*, 99-111.

McNally, B., Kumar, P., Hordatt, C., Mauriello, M. L., Naik, S., Norooz, L., Shorter, A., Golub, E., & Druin, A. (2018). Co-designing mobile online safety applications with children. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (p. 523). ACM.

Millen, D. R. (2000). Rapid ethnography: time deepening strategies for HCI field research. In *Proceedings of the Third Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques* (pp. 280-286). ACM.

Moser, S. C. (2016). Can science on transformation transform science? Lessons from co-design. *Current Opinion in Environmental Sustainability*, 20, 106-115.

Muller, M. J. (2009). Participatory design: the third space in HCI. In *Human-computer Interaction* (pp. 181-202). CRC press.

National Advisory Board on Research Ethics (2009). Ethical principles of research in the humanities and social and behavioural sciences and proposals for ethical review. Finnish Advisory Board on Research Integrity, Helsinki. Retrieved from http://www.tenk.fi/sites/tenk.fi/files/ethicalprinciples.pdf

Penuel, W. R., Roschelle, J., & Shechtman, N. (2007). Designing formative assessment software with teachers: An analysis of the co-design process. *Research and Practice in Technology Enhanced Learning*, 2(01), 51-74.

Prahalad, C. K., & Ramaswamy, V. (2004). Co-creation experiences: The next practice in value creation. *Journal of Interactive Marketing*, 18(3), 5-14.

Roschelle, J., & Penuel, W. R. (2006). Co-design of innovations with teachers: Definition and dynamics. In Proceedings of the Seventh *International Conference on Learning Sciences* (pp. 606-612). International Society of the Learning Sciences.

Sanders, E. B. N. (2002). From user-centered to participatory design approaches. In *Design and the Social Sciences* (pp. 18-25). CRC Press.

Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *Co-design*, 4(1), 5-18.

Sanders, E. B. N., & Westerlund, B. (2011). Experiencing, exploring and experimenting in and with co-design spaces. *Nordes*, (4).

Shrader, G., Williams, K., Lachance-Whitcomb, J., Finn, L. E., & Gomez, L. (2001, April). Participatory design of science curricula: The case for research for practice. In *Annual Meeting of the American Educational Research Association*, Seattle, WA.

Spinuzzi, C. (2005). The methodology of participatory design. Technical Communication, 52(2), 163-174.

Tomico, O., & Garcia, I. (2011). Designers and stakeholders defining design opportunities “In Situ” through co-reflection. In *Proceedings of the Third Conference on Participatory Innovation* (pp. 58-64).

Ulriksen, L. (2009). The implied student. *Studies in Higher Education*, 34(5), 517-532.

Yarnall, L., Shechtman, N., & Penuel, W. R. (2006). Using handheld computers to support improved classroom assessment in science: Results from a field trial. *Journal of Science Education and Technology*, 15(1), 1–17.

Ye, X., Zhang, B., & Chia, P. (2010). A tripartite model of co-designing for an iMVT integrated science curriculum. In S. L. Wong, S. C. Kong & F. -Y. Yu (Eds.), *Proceedings of the 18th International Conference on Computers in Education* (pp. 145-152). Putrajaya, Malaysia: Asia-Pacific Society for Computers in Education.

Appendix 1

Field observations template

Summary of main interests regarding data collection:

- Background of participants attending the festival
- Is there diversity among participants attending?
- To what extent are they self-motivated?
- How they behave (for instance: active, lurking...etc.)?
- Do they share what they see – discuss together on the things in the events
- To what extent are adults accompanying participants present in the festival?
- What is the background of the adult companions?
- What type of activities are offered at the Festival?
- What activities are most popular and what type of participants get attracted to them?
- Are the activities accessible? Can they be adapted based on different skill level?
- What are the backgrounds of the people involved as makers?
- What type of activities do they propose? Are they accessible to everyone?
- How do they facilitate the activities? Do they make special efforts to involve people who at first would not be very self-motivated?

Appendix 2

Questionnaire to makers at the maker festival

1. What is your name?

2. Where are you from?

3. What is your educational background?

4. Is your current professional practice connected to maker culture, DIY activities or science dissemination?

5. What activity are you proposing at Wärk:fest? Indicate some keywords that describe your activity

6. To whom are you addressing this activity?

7. In which language/s are you offering this activity?

8. What do you expect participants would get by taking part in your activity?

9. Is it the first time you take part in a maker event? If not, when was the last time you participated in a maker festival?

10. How did you hear about Wärk:fest?

11. Why did you decided to participate in Wärk:fest?

Follow-up questions semi-structured interviews to makers

- What aspects of your activity were more challenging for participants?
- In which aspects of your activity were participants more interested in?
- During your participation at the Wärk:fest, was there something that surprised you?
- What did you aimed to achieve with the activity you suggested?
- How well do you think you achieved that goal?
- Was it challenging to communicate with the participants? (this refers to knowledge, language barriers, age...)
- Did you notice big differences/ diversity among the people who got interested in your activity?
- Did you need to help participants use the tools involved in the activity? How familiar do you think participants were with the tools they use in your activity?

Appendix 3

Questionnaire about science educators' practices

Survey to collect information about science educators experiences on their regular practice. The data collected in this survey will help to the identification of challenges experienced by educators in their work practice. This information will be used to inform the co-design workshop that will take place next March 2019 in Helsinki[19]. All the answers and information shared by the survey respondents will be kept anonymous.

The estimated time to fill the survey is 20 minutes. In order to know about your work context, we would like to ask you to submit 3 images of the spaces and tasks you dedicated most of your time today. Please send the images to eva.durall(at)aalto.fi (indicate your name so we can match them to your survey answers). Thanks for your collaboration!

1/3 Background information

1.1 What is your name? Please provide a name (no need to be your real name) that we can link to the images

1.2 What is your age?

- Under 18
- 18 - 24 years old
- 25 - 34 years old
- 35 - 44 years old
- 45 - 54 years old
- Older than 54

1.3 What is your gender?

- Female
- Male
- Transgender
- Prefer not to say

1.4 What's your highest level of education?

- No formal education
- High school diploma
- College degree
- Vocational training
- Bachelor's degree
- Master's degree
- Professional degree
- Doctorate degree

[19] This questionnaire was shared with science educators before the the co-design workshop held in Helsinki on March 2019.

- Other:

1.5 In what field are your studies?

2/3 Current workplace

2.1 Where do you currently work?

2.2 What is your job title?

2.3 How long have you been working in science education?

- Less than one year
- 1 - 2 years
- 3 - 5 years
- More than 6 years

3/3 Work experiences during a workday

3.1 Provide 3 images of the spaces and tasks you dedicated most of your time today. Images can be also sent to eva.durall(at)aalto.fi

3.2 What did you do today?

3.3 With who did you interact in today's activities? Please provide general information about their age group, gender, and the task/activity they were involved in. In case you collaborated with work colleagues, specify that as well.

3.4 What did you do to catch participants' interest in the activity/ies you facilitated today?

3.5 How satisfied are you with the activities you facilitated today? (Likert scale from one to five, from very dissatisfied to very satisfied)

3.6 Did you experience a particularly successful or frustrating situation? If so, please describe it.

3.7 How frequently do the activities you facilitate support the following skills?

	Never	Rarely	Sometimes	Most of the time	Always
Creativity					
Collaboration					
Communication					

Self-management					
Information management					

3.8 How diverse are the groups of people attending to the activities you facilitate? (Likert scale from one to five, from not at all to extremely)

3.9 How challenging do you feel is to support the active participation of the following groups in the activities you facilitate?

	Not at all	Slightly	Moderately	Very	Extremely
Immigrants, refugees, and migrants					
Women and girls					
People with mental illness					
Children and youth					
People with physical impairments					
People with learning difficulties					
People from low socioeconomic background					
Other					

Appendix 4

“How Might We” trigger cards

About Inclusion:

How might we include diverse role models?

How might we encourage different ways of being and behaving?

How might we involve parents and guardians?

How might we tempt learners who might not travel to a science learning context?

How might we get rid of entrance fees?

How might we include learners who don't master the official language/s?

How might we prompt learners who don't feel capable?

How might we make learners feel smart and self-confident?

How might we lure in learners who might not be aware of non-formal science education activities?

How might we create a culture of inclusion?

How might we design disability-friendly activities and spaces?

How might we support cozy and relaxed spaces?

How might we foster collaboration between different type of learners and organisations?

How might we support learners gain a sense of achievement?

How might we be able to increase positive and engaging media presence?

How might we make science appealing and fascinating?

About engagement

How might we support different ways of interacting?

How might we support different type of experiences?

How might we foster collaboration between different learners?

How might we support transforming a learning space into a learning community?

how might we support learners set their own goals?

How might we trigger curiosity?

How might we support interest beyond the "wow effect"?

How might we encourage experimentation and perseverance?

How might we support a sense of achievement?

How might we support ownership and proudness?

How might we support awareness of one's own learning progress?

How might we build on learners' interests?

How might we encourage learners make connections between different experiences?

How might we make science appealing and fascinating?
How might we encourage learning and experimenting at home?
How might we measure impact?

About assessment and recognition
How might we support self-assessment of transdisciplinary thinking skills?
How might we recognise and assess learners' skills?
How might we identify people's expertise?
How might we measure impact?
How might we identify evidence of learning?
How might we encourage creative skills?
How might we foster critical thinking skills?
How might we support collaborative skills?
How might we support communication skills?
How might we accredit skills acquired through informal learning?
How might we recognise efforts for supporting inclusion and equity?
How might we recognise efforts for fostering engagement?
How might we encourage learners to just be and still take part?