SY STEM 2020

SCIENCE LEARNING OUTSIDE THECLASSROOM

WP 6 : EVALUATE

Deliverable 6.4

Final Evaluation and Impact Assessment Report

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Glossary of Terms

Acronym	Definition
H2020	Horizon 2020
WP	Work Package
STEM	Science, Technology, Engineering and Mathematics
STEAM	Science, Technology, Engineering, Arts and Mathematics
n	indicating the sample size
ESM	Experience Sampling Method

Table of Project Partners

Partner Name	Acronym	Partner Role	Country
Science Gallery at Trinity College Dublin	SGD/TCD	Coordinator, Research Partner, Practice Partner, WP1,5,8 Lead	Ireland
The European network of science centres and museums	Ecsite	Communication Partner, WP7 Lead	Belgium
Aalto University	Aalto	Research Partner, WP4 Lead	Finland
Zentrum Fur Soziale Innovation	ZSI	Research Partner, WP3,6 Lead	Austria
Stichting Waag Society	Waag	Practice Partner, WP 2 Lead	Netherlands
Ars Electronica	AE	Practice Partner	Austria
Kersnikova Institute	KI	Practice Partner	Slovenia
Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci	MUST	Practice Partner	Italy
LATRA EE	LATRA EE	Practice Partner	Greece
Centre for the Promotion of Science	CPN	Practice Partner	Serbia
Bloomfield Science Museum Jerusalem	BSMJ	Practice Partner	Israel

Table of Third Parties

Third Party Name	Acronym	Country
European Molecular Biology Laboratory	EMBL	Germany
Fachhochschule Nordwestschweiz	Raumschiff	Switzerland
Fundacao da Juventude	FJ	Portugal
Muzeiko Foundation	Muzeiko	Bulgaria
Association traces theories et reflexions sur l apprendre la communication et l education scientifiques	TRACES	France
Science Gallery at King's College London	SG London	UK
Uskupeni tesla obcanske sdruzeni	uTesla	Czech Republic
Flanders Technology International	Technopolis	Belgium
Kentro diadosis epistimon kai mouseio technologias idryma	NOESIS	Greece
Tom Tits Experiment AB	Tom Tits	Sweden
Consorcio parque de las ciencias	Parque de las Ciencias	Spain

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1 Introduction

This is the final report in Work Package 6 of the SySTEM 2020 project, and summarises the findings of the project and the assessment of their impacts. As such, the report has a broad focus which attempts to provide an overview of the project, drawing on findings from multiple tools and methods simultaneously, rather than to each tool and its findings specifically. The following sub-sections provide an overview of the project, and a road-map of the report.

1.1 SySTEM 2020

SySTEM 2020 is a multi-faceted project focused on evaluating the impact and delivery of science learning outside of the classroom. The project is coordinated by Science Gallery at Trinity College Dublin and comprises 11 Partners and 11 Third Parties in 19 countries across Europe and Israel. The project aims to develop a detailed understanding of science learning outside of the classroom as experienced by young learners between the ages of 9-21 years old in an array of contexts including those from geographically remote, socio-economically disadvantaged, minority, and migrant communities. The project has five key objectives;

- O1: To thoroughly assess existing informal and non-formal science learning in Europe
- O2: To establish challenges surrounding informal science education and identify necessary factors that support fair inclusion and engagement in this field by learners, involving multiple stakeholders and learners through a co-design format
- O3: To design consolidated frameworks and tools for facilitating informal science education, including a tool that can be used by STEM and STEAM learners to gain credentialisation
- O4: To reflect on and evaluate the impact of the pilot studies and adapt the learning tools accordingly to improve their efficacy
- O5: To disseminate the learnings of SySTEM 2020 via research papers, conferences and workshops, as well as to engage and inform stakeholders, peers and the general media to foster public awareness of the project

The project explores the ways in which science learning, attitudes and aptitudes, are influenced by learners' physical, emotional, social and cultural contexts. Across research and practice, SySTEM 2020 explores equity in relation to science learning, which is considered crucial in exploring who is able to engage with science, how and why. Our reasoning for considerations of equity is based on Bourdieu's description of cultural reproduction which results in learning environments reflecting and reinforcing the dominance of privileged groups to the detriment of non-dominant individuals and communities (Bourdieu & Passeron, 1990). Archer et al. (2015) extend this system to science and science learning, demonstrating the importance of power structures in science engagement. Through exploring diverse learners' experiences of science education, further understanding of and support for equity in science learning will be achieved.

Deliverable 2.1 (Conceptual Framework) describes learning outside of the classroom as a broad spectrum of activities in which learners can experience a huge diversity of contexts, with differing intentions and outcomes. This broad spectrum of experience makes up a learning ecology (Bevan, 2016) in which knowledge is constructed by learners with influence from their physical, social and cultural contexts. These contexts include formal learning experiences (e.g. school classrooms), non-formal learning experiences (e.g. museums, makerspaces) and informal learning experiences (e.g. media consumption), all contributing to the construct of diverse and varied learning ecologies where learners interact with and reinforce one another.

This deliverable reflects on the project from a multitude of perspectives; that of the learners, the institutions, and how this contributes to broader society. The focus is to evaluate and elaborate the meaning of the project and its impact.

1.2 Purpose of Report

This report, as the final evaluative deliverable for SySTEM 2020, draws from and is overlapping with all other project work packages and their deliverables. Its purpose is to provide a birds-eye view of what the project has offered to the field of research and practice, firstly by summarising and reflecting on process and findings (responding to objectives 1, 2 and 3), and secondly by interrogating the lasting impact of these findings and their associated activity (responding to objectives 4 and 5). The report is framed around three key questions:

1. How is science learning experienced by learners?
2. How can institutions support and further science learning in non-formal and informal contexts?
3. What has the impact of the project research and practical activity on learners, institutions, and the wider science learning field?

The first two questions deal with the lessons learned; consolidating results from tools such as the SySTEM 2020 map (WP2), the longitudinal survey and learning portfolios (WP3), equity-focussed co-design processes (WP4), self-reflection and evaluation tools (WP5) and the experience sampling method (WP6). The final question was set to enable a meta-analysis of the long term effects of the aforementioned tools, methods and activities. Bringing all of this together is the work of WP6, but is somewhat inseparable from other work packages within the project.

Following this introduction, the report addresses each of the above questions in order. In Section 2, the focus is on the learners' perspectives, as understood through the tools developed in WP3 and WP5. Section 3 explores what has been learned about how informal science learning institutions can further support equitable science learning experiences for learners', drawing largely on WP4, supported by the SySTEM 2020 community seeded by the map in WP2. Section 4 draws from a number of impact surveys and impact assessment interviews to identify lasting effects of this activity on learners, the SySTEM 2020 consortium, further science learning organisations, and the field of science learning and practice at large. Finally, these impacts are mapped across social, technical, political and economic realms, to demonstrate the varied and extensive contributions the project has made within Europe. Section 5 serves as an opportunity to review and discuss how this all fits together, and what future implications and potentials are within the field.

1.3 Overview of Findings

Learners

In Section 2, the project's findings are summarised in terms of what has been understood of learners' experiences of science learning. The insight is based on young people (aged 9-21) and their encounters with non-formal science learning through SySTEM 2020 practice partners. The insights are gathered via quantitative and qualitative research and evaluation tools developed by SySTEM 2020 research partners; Science Gallery Dublin, Aalto University and ZSI.

Three key questions are explored in this section;

- How do young people experience science learning?
- How is science learning relevant to young people?
- What are learners' perspectives on recognising science learning outside of school?

The first question is answered via the three lenses introduced in D6.1 (Common Evaluation Framework); emotional, cognitive and behavioural aspects of learning. Each tool provides a distinct perspective on each lens, which helps to build a complex understanding of learners' experiences.

The Experience Sampling Method (ESM) and longitudinal survey reinforce that positive emotions are important in science learning, particularly positive emotions from learning in other contexts, such as at school or home[1]. Yet, the power of a complexity of differing emotions and the roles that they play in learning becomes increasingly evident through qualitative tools. The zines in particular help to highlight that learners can experience adversity and challenge, but still take positives out of the experience, or that topics that elicit negative emotions are still powerful learning experiences that can motivate learners to effect change. This is particularly relevant in light of the nature of multi- and transdisciplinarity in the consortium, whereby learning is explored through a variety of different lenses, creating a rich and varied experience for learners.

In terms of behavioural learning, learners' relationships with science are strongly influenced by habits, which might reinforce a connection with, or a disassociation from science. However, SySTEM 2020 findings support earlier research, reporting that these habits are not equally developed and experienced by learners from different backgrounds; whereby learners from more dominant backgrounds are more likely to form a connection with science through their habitual behaviour than those from less privileged backgrounds (Archer et al., 2012). The qualitative evaluation tools used in the project help to demonstrate that positive experiences in non-formal science learning can have an effect on learners' behaviours beyond that experience, potentially making science habits more of a possibility at home, school or elsewhere for learners for whom that might not be the case.

Impressions of learners' cognitive ability with relation to science is strongly influenced by their school environments and associated grades and/or feedback. This then goes onto interact with and reinforce emotional learning (enjoying science because they are good at it) and behavioural learning (doing more science because they are good at it and as such enjoy it). SySTEM 2020 has explored with reframing cognitive skills in science, inviting learners to rate their own creativity, communication, critical thinking and collaboration in relation to science learning experiences. The results from the studies conducted in the SySTEM 2020 demonstrate that learners gain confidence in their abilities as they relate to science, which illuminates an important potential pathway to

[1] See D6.2 Analysis of Individual Mapping and Learning Portfolios

reframe science engagement such that it welcomes students with a wider diversity of academic achievement in formal settings, which in turn can interact with and reinforce positive emotions in relation to science learning, and as such, potentially foster further science habits and behaviours.

The second question explores what aspects of science learning is relevant to learners. Through qualitative open-ended questions, three areas of relevance are isolated as salient relevant parts of science learning for young people. These are; societal importance (of the content), enjoyment (of the process of content) and usefulness (of the process or content). Quotes from learners, collected as part of the qualitative research, are used in this section to demonstrate the diversity of meaning that is important within each of these three themes.

The final question of this section builds on the conception of critically reimagining 'success' and 'achievement' in science learning. SySTEM 2020 trialled the use of novel credentials to recognise diverse science learning that takes place outside of schools, drawing on interviews conducted with learners in relation to the idea of such accreditation was necessary in order to answer this question. While learners' opinions of the usefulness of this kind of tool unsurprisingly differed by context, there is a general consensus that while such a credential would be nice, it is not yet supported by recognition systems for it to have any real value for learners beyond acting as a memorandum of a fun experience. This leaves a challenge for practitioners to enable learners to own and recognise their non-formal science learning experiences in ways that hold value, such to further learning on cognitive, behavioural and emotional axes.

Science learning institutions

Section 3 draws from work within Work Packages 2 and 4, which were concerned with creating an interactive map of science learning organisations and using co-design approaches to draw insight from across the consortium to develop solutions to issues of inequity in science learning respectively. The section addresses the following question:

How has SySTEM 2020 supported institutions and educators to further equitable science learning experiences in non-formal and informal contexts?

SySTEM 2020 set out to promote and facilitate equitable access to science learning for all young people across Europe. In order to do this, the project has produced outputs and findings relevant for learners directly, discussed above. Yet, further to this, the project has also worked to develop a number of resources which may support educators and institutions who are working to deliver and facilitate science learning outside the classroom. By gathering research results across 19 countries and working in collaboration with a group of international experts and young science learners, the consortium has developed research findings, tools, and policy recommendations which support science learning institutions to further equity in learning[2]. In particular, this section expands on:

- The values of a participatory approach to planning and design
- Challenges related to inclusion, engagement, and assessment and recognition of learning
- The difficulty in applying the generalised set of design principles[3] to support non-formal science educators were developed in specific contexts or setting
- The production of a White Paper on Equity to highlight the key areas requiring action and strategies to this in relation to a systemic issue
- The value of a map of organisations and activities[4] offering science education outside the classroom in 25 countries, and the learnings that this map has provided
- The ongoing questions around the use of standardised credentials to recognise learning in non-formal environments

Impacts of the SySTEM 2020 Project

The overview of impact at the project level helps to illustrate how the myriad research and outputs (which are reflected on in Sections 2 and 3) have, and might continue to, impact the science learning community. The section also shares some key figures about what SySTEM 2020 has achieved:

- Engaged over 4000 learners
- Supported over 170 workshops and learning activities
- Contributions from over 180 science learning and engagement professionals
- Hosted 18 webinars, engaging a further 500 science learning professionals
- Met with 5 policy makers in order to further discussions about the role of non-formal science learning in education
- Presented at 17 conferences across Europe

[2] D4.1 Report on Co-Design Sessions, D4.2 Design Principles and Methods Toolkit and D4.3 Whitepaper on Equity-Focused Science Learning Outside the Classroom.
[3] This is found in D4.2 Design Principles and Methods Toolkit
[4] www.system2020.eu/the-map

- Produced 4 peer reviewed academic papers, with one further paper currently in review
- Seeded future project proposals, of which some are currently in development or submitted for consideration.

Impacts from the project and linked activities are explored on four levels, which interlink, reinforce and interact. These levels, used as a model in which to situate impact case studies, are; the learners, the SySTEM 2020 consortium, organisations beyond SySTEM 2020, and the wider science learning community including government bodies, schools and NGOs. Impacts within each of these levels is discussed below.

SySTEM 2020 has an objective not only to impact learners during the course of the three-year project, but to continue to impact learners in the future through organisational changes and approaches made possible by the project. However, for the purposes of this report, the impact at a learner level is explored in terms of learners the project has already been able to interact with and influence. The key findings, presented in this section, are that there are clear examples of organisations being able to welcome more learners, and importantly, more learners from diverse backgrounds, to their activities as a result of SySTEM 2020. Many of those learners had meaningful and enjoyable experiences, which stretched beyond science learning and into further aspects of their lives, as exemplified by this quote, "I now trust in myself more... I am more confident to share my opinion".

Within the SySTEM 2020 consortium organisations, there are many examples of impact on personal staff growth as well as on practice and future strategic direction. Case studies exemplify that a process of critiquing, adapting and absorbing SySTEM 2020 approaches and findings takes place in both formalised and more casual, unplanned ways. While some organisations are still developing plans as to what role the project tools will take in the future, others have planned and delivered training programmes based on the Design Principles and Methods Toolkit, or used the Toolkit to plan their future learning programmes with accessibility and equity in mind.

Organisations who are a part of the consortium also exist within their own networks and communities of practice. As such, it has been simple to identify examples of the ways in which the project has had influence beyond SySTEM 2020 organisations. In particular, the SySTEM 2020 map has helped to seed further connections and opportunities for collaboration. Two organisational case studies in this section of the report present practice sharing and training that facilitated science learning experiences through different institutions in their nations.

Finally, the impact of the project on the nebulous 'science learning community' is explored. Conferences, publications, social media and online presence[5] contribute to this a great deal, but can be difficult to measure or to get meaningful qualitative feedback from. This section uses two in depth case studies demonstrate organisations impacting their communities nationally and internationally via their reputation and expertise resulting from the SySTEM 2020 project. These examples range from national research and practice projects, to the online map being co-opted by a local city council.

2 Understanding informal science learning from the learners' perspective

SySTEM 2020 explored science learning outside the classroom in informal and free-choice contexts particularly as it is experienced by young people aged from 9 up to 21 years old. The project research tools were designed specifically to be used by young people and to serve as an insight into their experiences of and the resulting benefits and/or disadvantages of informal science learning. As such, this section summarises what can be learned about science learning from the perspective of learners that the consortium serves through their practice. In particular, this section consolidates findings from: workshops with learners carried out in all of the Partner and Third-Party institutions; the longitudinal science learner survey, the Experience Sampling Method (ESM)[6] and learning portfolio zine tool[7]; the self-reflection tool, self-evaluation tool, credentialisation trials[8], and observation mapper[9].

In total, over 4000[10] young learners were involved in the activities of the project. The findings of the individual tools as well as elaborations on the design and the testing of the tools can be found in D3.2 (Longitudinal Survey), D3.3 (Learning Portfolios), D5.3 (Observation Mapper), D5.4 (Self-assessment and Credentialisation tools) and D6.2 (ESM, Survey & Learning Portfolios).

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[5] Social media and online activity will be reported on in D7.4 Report on all Communication and Dissemination Activities
[6] See D3.2 Report on Survey Results and D6.2 Analysis on Individual Mapping and Learning Portfolios.
[7] See D3.3 Report on the Production of Learning Portfolios and D6.2 Analysis of Individual Mapping and Learning Portfolios.
[8] D5.4 Report on Testbed Educational Programmes.
[9] D5.3 Templates, Data Collection and Visualisations.
[10] Here we refer to all learners who took part in activities funded by SySTEM 2020, rather than 2890 learners who engaged specifically in the project research through using project tools.

2.1 What is informal science learning?

Before exploring informal science learning from learners' perspectives, it is important to define what this term refers to, and in which specific settings the SySTEM 2020 learners will have encountered it. Learning is a socially embedded, cognitive, emotional and behavioural process (Falk et al., 2016; Carlone & Johnson, 2007) which takes place within a complex learning ecosystem, a "learning ecology", which is specific to each learner and influenced by their physical, social and cultural contexts (Bevan, 2016). While learning can take place anywhere, at any time, with anyone, and is highly personalised, it is sometimes useful to categorise learning such that contributions to learners' experiences can be understood individually. Though it is recognised that due to the interconnected ecological nature of learning, any categorisation serves a purpose of practicality, rather than a reflection on any true divides within or between types of learning. Therefore, D2.1 (Conceptual Framework) provides a useful and suitably graded definition of how informal learning and formal learning differ. While the latter takes place primarily in school environments, following curricula that address specific learning outcomes, and testing this through assessment; the former is casual, open-ended, and often unexpected.

Informal learning can take place through conversations, television programmes, podcasts, or visits to outdoor spaces (Falk, 2001). Often learning within museums, galleries and nature reserves also gets termed as informal learning (Bell et al., 2009), though D2.1 suggests that such experiences are more aptly named 'non-formal' due to the level of intent that often accompanies such activities. Across the literature 'informal' is used widely, and tends to refer to learning that is not formal, and does not occur in school. The difficulty of these terms is remarked by Falk (2005), who sets out a reasoning for adopting the term free-choice learning, to refer to learning that is encountered on learners' own terms, which he argues is of more importance than where or how it might take place.

Within SySTEM 2020, Third Parties and Practice Partners offer non-formal, free-choice learning activities, and it is in these contexts that the learners contributed to and took part in the project. However, the research explored more than just the learners' experiences of these non-formal programmes, and instead aimed to understand how such experiences interact with other aspects of their lives, including family influences, hobbies, habits and more. As such, the expanded term of 'informal science learning' was considered suitable. In this project the term informal is used to comprise of non-formal experiences, personal reflection, informal conversations and experiences with peers and family members, and habits and hobbies that sit outside of the realm of 'science' but play a part in learners' personalised learning ecosystem.

Yet informal science learning is not dependent solely on places, habits and hobbies, but takes place primarily within learners themselves and is highly personal. Earlier research has considered learning as emotional (Bell, Shouse, & Feder, 2009), cognitive (Falk et al. 2016) and behavioural, a model which is also used in formal settings (Fredricks et al., 2004), and as such tools were developed which explored all three of these aspects in engagement and learning. Drawing from DeWitt and colleagues (2013) and Falk et al. (2016), SySTEM 2020 explored positive science attitudes and non-identification with science that arises from varied emotional, cognitive and behavioural learning experiences and habits. Positive science attitudes describe feelings such as science enjoyment, being interested in science and seeing how science relates to one's own life. In contrast, 'non-identification with science' describes the incompatibility of one's self-concept with science learning and scientific content.

Investigating factors that influence the ways young people experience science and science learning can benefit from the integration of multiple perspectives and research approaches, which aim to assess the learning process itself and which take the learner's individual ecosystem into account. To achieve this aim in SySTEM 2020, a multitude of research tools were used. In terms of quantitative tools, traditional survey methods providing a global assessment of the science attitudes and science engagement of young learners (termed the longitudinal survey), were combined with time sensitive survey methods providing information on the variability of the learning process (termed the Experience Sampling Method or ESM). Two self-assessment tools, the self-evaluation and self-reflection tool, used quantitative and qualitative data to provide an understanding of the change in learners' specific skills during science learning activity. While two further qualitative approaches, the learning portfolios and the observation mapper, allowed young learners to document and reflect on their learning experiences and observations made during STEAM workshops. Using these different tools enabled the development of an integrated understanding of the different components of learners' experiences and their interrelation.

2.2 How do young people experience science learning?

In answering this question, multiple data sets including the ESM, the longitudinal survey, the self-reflection and self-evaluation tools, the observation mapper and the learning portfolios were used to explore what was learned about young people's experiences with informal science learning through the lenses of emotion, behaviour and cognition (Fredricks et al., 2004; Carlone & Johnson, 2007). It is important to note that these three areas are not entirely separable, but interrelate and reinforce one another. Neither is experiencing science learning separated by context; an emotional experience in a formal environment can affect a behavioural experience in informal science learning experience and vice versa.

Emotionally

In this section, feelings about science and the development of perceptions of science are explored. Feelings and emotions during learning hold strength and have lasting effects on learners (Zembylas, 2005), a finding which is reinforced by many research tools throughout the SySTEM 2020 project. Positive emotional experiences during science learning can build learners' connections to science. In particular, **the longitudinal survey found that the enjoyment of science lessons in school is an important predictor of liking science more generally, demonstrating that emotional experiences in one context will affect science learning and science attitudes in other areas of life**. What's more, young people were also affected by their peers and family members; the longitudinal survey found that a learner was more likely to develop a positive science attitude if their friends and family consider science relevant and enjoy to discuss and explore it together. Beyond the quantitative contribution of the longitudinal survey, which was able to identify links between positive science attitudes and statements related to enjoyment, the self-reflection tool consisted of open responses and enabled to gather an insight, in learners' own terms about how experiences of emotion in non-formal activities and programmes affected them.[11]

> *"We learned about sound and sound waves and it was fun"*
>
> *"Space lab. It was so cool that you could see the universe in 3D!"*
>
> *"We were playing, having fun, explored and worked."*
>
> *"I studied astronomy, birds, plants and history. I was active, constantly in motion what I really liked."*
>
> *"We dealt with astronomy, which was very fun."*
>
> *"I took part in the constellation crafting workshop. During the workshop, we learned all about stars and constellations and we then discussed the stories and mythology behind them. The workshop was really fun and I enjoyed it alot!"*

[11] These quotes come from learners reflecting on workshops they took part in at AE, BSMJ, CPN and SGD.

"...but this is more creative and fun"

While positive emotions might seem the most obvious contributors to developing meaningful connections with science, less positive emotions can also play a role in demonstrating the value of science or resulting in learner motivation. This is particularly relevant in learning about the environment or climate change, where emotions of guilt and shock can contribute to further dedication to science learning and action (Stapleton, 2019) if managed correctly, or on the contrary can result in disengagement and depression (Ojala, 2012). **These divergent outcomes demonstrate the importance of mediating learning experiences to harness emotions in order to result in positive action and experiences.**

The observation mapper used such an approach, by inviting learners to engage with and develop ownership over both positive and negative phenomena through a scientific lens. For instance, the observation mapper was used to map litter (as was the case in trials in Austria), invasive weeds (trials in Slovenia) or evidence of positive/negative culture in a city locked down due to coronavirus (trials in Ireland). In each of these mapping experiences, the learners were given the power to 'categorise' the phenomena they were mapping, to visualise this digitally, and to reflect on it. In trials in Dublin, learners also defined the terms of what they mapped and set the categories themselves. Such processes seemed to enable a critical reflection on the positive and negative findings, which led to action and positive engagement, as opposed to depression or despair.

The learning portfolio, as a free-form qualitative research and evaluation tool, was an open canvas in which learners could express themselves and reflect on their experiences within non-formal workshops and informal science learning more widely. This tool demonstrated clearly the importance and continued salience of emotionality during science learning experiences, which was identifiable (in positive and negative forms) within the majority of completed zines.

For example, learners who did not enjoy the workshop and/or the zine-making process made this very clear through their apparent frustration in the finalised zines. Examples of dissent related to their non-formal learning experiences included scribbling and written explanations. This was apparent in two cases, both from Kersnikova in Slovenia, whereby learners expressed the following;

"I have learned not to trust leaders. zines are miserable"

"it annoys me that I have to do zines"

In both of these cases, the emotions are negative. The first quote demonstrates that something during the learning experiences resulted in a lack of trust for 'leaders', which likely relates to the facilitators of the workshop. Both quotes demonstrate negative emotions towards zine-making. While such a free-form evaluation exercise is useful in making this discontent apparent, it is also necessary that learners are supported to navigate, reframe, and reject experiences that they do not enjoy in favour of something that will serve them more positively. As such, **zines (and all workshop content) are not a one-size-fits-all for learners, and learning approaches, tools and methods should be approached creatively such that they can be adapted or rejected to result in positive and constructive experiences that will serve learners.**

It is worth noting that this unique nature of zines to encourage learners to share what they don't like is powerful. In contrast, the self-reflection tool received no responses that explicitly mentioned a lack of enjoyment, but did see far more empty responses, and a few learners who could not recall what they did during their workshops, as shown below. These responses indicate that the workshop was unlikely to have captured the learners' attention. However, blank responses received via the self-reflection tool did not help to understand whether the workshop or the evaluation tool hindered the learner's enjoyment, and so is not as instructive as zines are in terms of improving the experience for learners[12].

> *"I have no idea"*
>
> *"do not remember"*

The zine samples also demonstrated many examples of positive emotions, which helps to illustrate how the emotionality of a science learning experience remains salient and significant to learners when they reflect on the experience. The following quotes are from Science Gallery Dublin, Ireland, Ars Electronica, Austria and Kersnikova, Slovenia;

> *"highlight of the week was the drama workshop because everyone was just having fun. made me feel comfortable about sharing ideas and expressing myself"*
>
> *"our project has pushed us the most … unique … very special … bursting with enthusiasm!"*
>
> *"making great experiences with great people"*
>
> *"smart is fun"*

The first three quotes specifically draw on learning/social experiences and demonstrate the value in these with their enjoyment. The final quote is more abstract but draws

[12] These responses came from learners who took part in workshops at BSMJ.

together emotionality (fun) with learning/science/the content of the workshop (smart). Such quotes are in good company, with other learners expressing themselves through still more abstract means e.g. smiley faces and decorated expressive words "FUN".

Finally, as mentioned above, emotions do not simply fall into positive and negative which reinforce and distance learners from science engagement respectively. **Learners encounter and appreciate the complexity of the world around them and the idea of a push and pull in terms of emotional experience and positive action or outcome.** The following quotes demonstrate this[13];

> *"I feel more strongly that plastic is bad for the environment and is making landfills bigger"*
>
> *"mistakes make me angry and I learn from them"*
>
> *"when I make a mistake I sometimes get angry and then I correct the mistake"*
>
> *"It's hard to make a robot, connect, make a housing, find the right program ... There's a lot to adapt."*

The first quote reflects a growing understanding of the negative effects of plastic on the environment, but this negative emotion does not necessarily correlate to a negative learning experience or a negative connotation of science. As Ojala & Bengtsson (2019) show, there are many different ways of navigating learners' understanding of environmental peril, but being aware of the problems is often considered the first step in environmental learning (Stapp et al., 1969). The next two quotes are really interesting in that the learners themselves are reflecting on how a process linked to a negative emotion can result in a positive outcome. Similarly, the final quote reflects on the difficulty of a task, but not in a purely negative way, this quote perhaps shows appreciation for the complexity of the workshop, and as such, the leaner's achievements.

Combining the results of these various tools in such a way demonstrates that emotion does play an important, yet varied, role in learners' experiences of science and science learning. Most importantly, it demonstrates that learners reflect on emotion, and they themselves navigate its complexity, and should be continually empowered to do so during learning experiences.

[13] These quotes come from learners who took part in workshops at SGD and Kersnikova.

Behaviourally

Here the experiential aspect of science learning; the behaviour and activity that is undertaken in an educational context, as well as the longer term behavioural habits of learners, both of which contribute to learners' relationship with science, are explored.

The longitudinal survey and ESM explored the everyday science engagement of young learners by asking which science learning activities they engaged in. The research cast a broad net in terms of science related activities, drawing from Falk et. al. (2016). Art-based science learning (playing music instruments, participating in drama or action classes and dance, which can foster informal science learning), team sport based (informal) science learning, self-directed science learning (watching videos about science, doing experiments at home, repairing things) were all included. The survey found that 23% of learners engaged regularly in self-directed learning outside of school, while 25% took part in art-based learning that could foster informal science learning. Partaking in these activities correlates with the development of a generally positive science attitude, demonstrating that habits contribute to learners' experiences of and perceptions of science.

Yet, habits and behaviours differ between and within individuals. **The ESM and the longitudinal survey helped to indicate the effects of age, gender and educational background (an indicator of class) on science behaviours, reinforcing findings that science engagement is not equally experienced by all** (Archer et al., 2013; Archer et al., 2021).

In general, age seems to exert an influence on the level of engagement in diverse science-linked activities. While younger learners generally engage strongly across many activities, older students' engagement in science seems to be strongly related to their science interest. Those interested in science tend to actively engage more in science related activities, whilst those who self-report as less interested pursue other activities instead. This might support findings of earlier studies, indicating that most people's science attitudes are rather fixed at the age of 14 (Archer et al. 2013; Hazari, Sadler, & Sonnert 2013), at which point learners might feel more able to direct their engagement according to their preferences.

Differences by gender can be seen when investigating science learning habits - both the ESM and the longitudinal survey indicated that male learners tend to engage in science learning more often as a self-directed activity, while female learners tend to take part in science learning and science engagement more often as a situation of sharing information with others. Emphasizing the importance of the primary socialisation at home, there is a strong influence of the social background of young learners and their familial educational capital on the probability to develop a positive science attitude, engage with science formally and informally and to identify with science. The higher the educational capital of young learners, the higher the probability they do enjoy science learning and find their own identity and habitual activities compatible with science.

While the ESM and longitudinal survey enable an understanding of the existing habits and behaviours of learners with relation to science learning, the more qualitative tools such as the zines and the SRT enable a deeper understanding of how learners assign importance to past, existing or future behaviour with regard to science learning. This, in turn adds to our understanding of behavioural learning.

In the self-evaluation and reflection tools, learners related their experiences to their habits more widely. In such a way, learners demonstrated how the experience can interact with their pre-existing behaviours and habits, or forge new habits in the context of their lives, rather than solely within science learning contexts[14].

> *"I think it's good to think about what we look for in a community now that we have space to reflect on community, as were all fairly disconnected at this time. It's also important to consider how others in your communities experiences might differ from yours, and how you can account for and accommodate for that"*
>
> *"I tell it [about the activity] to my mother and father and I did it at home."*
>
> *"I would like to do more in my free time with robots."*
>
> *"I might try look up recipes to use leftovers better"*

It is interesting to see that the learners' behaviours on occasion might be affected by the wider context in their personal lives, such as family, but also by their wider personal behaviour in relation to their role in a society, such as considering what other learners and communities might perceive about a topic. There were also examples of the experiences contributing to learners' future plans as to how to adapt their learning behaviours and habits in the future.

> *"It will help me and my friends become better in school"*
>
> *"I will try harder with the exercises I have to do at home"*

[14] These quotes are from SGD, LATRA, AE and Waag.

This might be an example of learners applying things they've learned or encountered in non-formal contexts to formal education, demonstrating that habits and behaviours across the formal/informal divide are linked and influenced by one another.

The zines showed a similar pattern, whereby learners both reflected on how their wider habits and behaviours intersected with the learning experience, as well as linking the experience specifically to other instances of learning in formal/non-formal and informal environments;

> *"In my everyday life it is hard to find European values"*
>
> *"In school I learned about democracy and in LATRAs workshop about democracy in Europe"*
>
> *"I can say that much of what I used in the film I acquired during the school years. Of course, I learned a lot in the process of making the film, but I adapted the basic knowledge from school."*

These findings help to demonstrate that habits and experiences within science learning are highly interrelated between formal, non-formal and informal contexts, between learners' self-directed and school-led learning. Importantly, behavioural science learning is affected by norms and personal situation, with learners from more dominant backgrounds more frequently taking part in, and therefore benefiting from, informal and non-formal science learning experiences. **These findings together highlight the importance of science learning across the formal-informal spectrum to work to welcome a higher diversity of learners and work to make science relevant for them, such that it can become a part of their habitual behaviour on their own terms**.

Cognitively

Finally, the cognitive aspect of science learning is explored. This is considered as relating to learners' perceived skills within science, their reflection on scientific content, and their experiences of scientific achievement across various learning contexts. These aspects are particularly interesting when considering informal science learning, since science is a field which espouses 'right' and 'wrong', which could contribute to the way learners reflect on their own ability.

The longitudinal survey data goes some way to demonstrating how assessment of science ability in formal contexts affects learners' experiences of and engagement with science in other settings. In the SySTEM 2020 project it was found that learners who self-report higher performance in science at school are more likely to exhibit a positive science attitude, emphasising the link between the formal education system, a perception of ability, and personal attitude towards science.

The self-evaluation and self-reflection tools used within the project go some way to reframing the idea of achievement in science, taking recognition into the hands of the learners themselves and encouraging them to mark their own progress, and reflect on their abilities and improvements. In particular, the self-evaluation tool encouraged learners to rate their own perception of their ability in relation to one of four core 21st century skills; creativity, collaboration, communication, critical thinking. Learners used this self-evaluation tool on every day of a multi-day workshop series at one of the SySTEM 2020 practice partner locations. Learners' ratings of their ability in these specific skill areas went up day after day, with the reported confidence in skill increasing from 2.2 to 2.4 on average, on a scale from 1- very little confidence, to 3 - very confident. The average score within partner locations did not differ significantly from one another (σ = 0.18 for the pre-evaluation confidence, and σ = 0.14 for the post-evaluation confidence). This result shows a positive effect of self-assessment to the understanding of the skills and the perceived confidence in their use, even though this effect is only moderate.

Confidence	AE	CPN	KI	LATRA	MUST	SGD	Waag	Average Confidence
Initial	2.3	2.5	2.3	2.2	2	2	2.2	2.2
Final	2.5	2.63	2.43	2.25	2.34	2.28	2.3	2.4

Table 1: Self-evaluation confidence scores

Within the self-reflection survey[15], learners were encouraged to reflect on their own learning and experience critically, with the question: *What would you do differently next time?* The results were varied, with many learners being satisfied (or perhaps being less engaged in the question) and so answering with short terms indicating that they would change nothing. Others could see opportunities to improve and expressed a want to do so:

> *"I would be more open to express my thoughts"*
>
> *"think a little more"*
>
> *"I would think before I started about what I would write and draw about"*
>
> *"I will participate more in class"*

[15] The differences between the self-evaluation and self-reflection tools are explained in D5.4 & D5.5.

This kind of cognitive engagement shows that learners' own reflections on an educational experience can reinforce learning in the future, potentially strengthening science engagement and perceptions in the future.

Zines also go some way to providing space for learners' own reflections on their achievement during an activity, though this is a little less common than within the self-reflection surveys, since there is no question that specifically asks learners to reflect on their own ability, learning or achievements. Nevertheless, the fact that some learners chose to reflect on their learning in such a way further demonstrates the importance of cognitive learning within a holistic learning experience. Some of the quotes that demonstrate cognitive engagement in their own learning are;

> *"I learned to value the opinion of others"*
>
> *"we learned to see correlations between the sciences and the arts"*
>
> *"if you make a mistake it can be corrected and there is nothing wrong"*
>
> *"I did not know so many things about equality"*

All of these show that instances whereby learners recognise that they have been changed or influenced by the educational experience, demonstrating a cognitive shift and awareness of learning taking place.

The concept of cognition was further explored in terms of scientific understanding through the longitudinal survey which explored learners' reflections on content within science learning. 80% of all surveyed young learners pointed out that they are interested in *specific* science-related topics, rather than science as a broad catch all subject. When asked which topics they were most interested in, interest in the human body and genetics, animals, computers and planets were named most frequently as shown in Figure 1 (below).

Though science subjects as categorised in school do feature in the responses (biology and chemistry are particularly noticeable), they were referred to less by learners than more specific and situated terms such as 'body', 'human', 'computer', 'animals', and 'planets'. Perhaps the use of these terms indicates that 'everyday' examples of science are of particular interest to learners. Compared to the nebulous nature of chemistry which is perhaps hard to directly encounter, many of us have seen a planet at night, used a computer, or interacted with animals. Everyone who answered this survey was a human and had a body, perhaps explaining why these topics of ultimate relevance are also of utmost importance to learners.

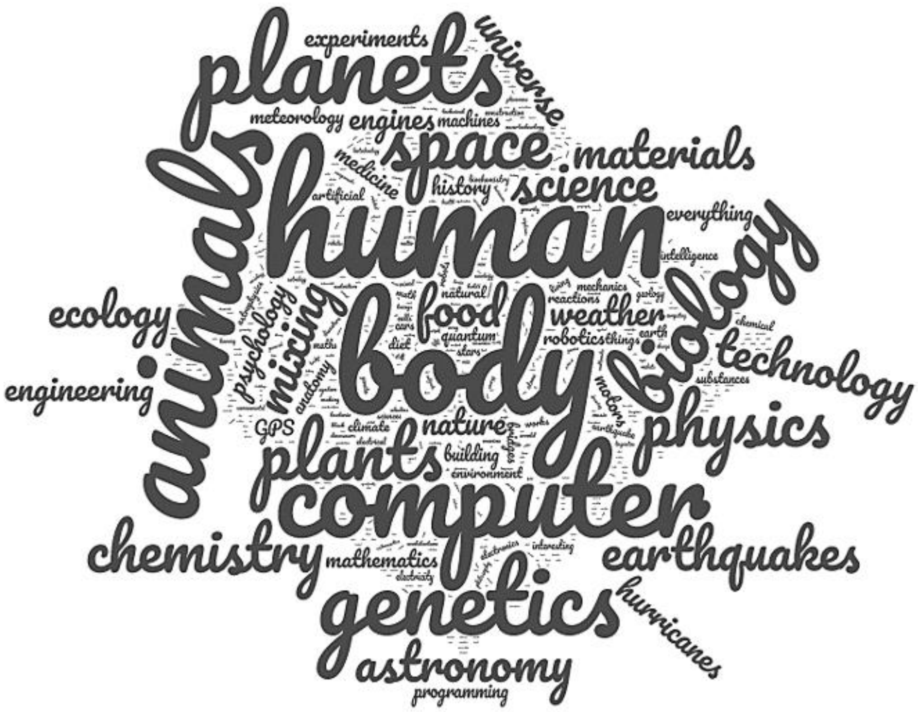

Figure 1: Longitudinal Survey, Wave 2: Which science topics do you find particularly interesting? (open text response, n=882)

The next section provides space to continue to think about how relevance impacts learning experiences in non-formal learning institutions, and how this links to larger science learning ecologies.

2.3 How is informal science learning relevant to young people?

Section 2.2 explored learning in young people along three pre-defined axes that reinforce and interact with one another. In contrast, this section moves on to explore themes of science learning relevance which emerged from learners themselves through the use of qualitative tools. The zines and the self-reflection tool both explored how science learning experiences contributed to the wider learning ecology of young people in terms of other experiences/knowledge that the activity interacted with, and how it might have a lasting effect on them in the future. It is these areas of interaction, and the ways in which learners delineate and unite formal/non-formal/informal experiences that will be discussed here, in order to build an understanding of what makes science learning relevant and important to young people.

It is worth noting that responses to questions within zines and the self-evaluation and self-reflection tools are influenced by both the workshop/programme that the participants partake in *and* their experience with the tool used to reflect on this. That is to say that the responses gathered from learners do not just reflect on the relevance of the programme, but also the relevance of the experience with evaluation tool. For instance, if a programme was really exciting and important but learners felt that the tool they used to reflect on the experience was boring, unengaging and irrelevant, they would be much less likely to submit a meaningful response. Similarly, if the experience of the workshop was boring and dull, the likelihood of wanting to invest time to reflect on it is likely lower, reducing the ability of the tool to provide an insight into that experience. As such, the understanding that can be drawn from learners about how science learning is relevant to them is affected both by the experiences that they have had engaging with SySTEM 2020 consortium institutions, and by their experiences with the SySTEM 2020 research and evaluation tools.

Thematic coding of young people's responses to the self-reflection tool helped to identify three areas where relevance arises for learners; (1) the societal importance of the content in the workshop, (2) the enjoyment of the process of the activities within the workshops/programmes, and (3) the personal usefulness of the programme and/or the content. Below are some quotes from learners who attended a variety of workshops across Europe during the final year of the SySTEM 2020 project.

(1) Societal/Global Importance (of the content)

> *"It sparks a conversation about confronting our own biases. This is really topical these days as we work towards dismantling systemic racism world wide [sic]. We all have bias and sometimes we can't pinpoint where we picked up that belief. This topic really opens your eyes to deconstructing harmful beliefs and also makes people more critical of the media they consume, ensuring a non-biased and balanced view"*

> *"The stars are cool and I like learning about them. I think the part were [sic] we talked about how different constellations were viewed from the perspectives of different cultures [sic] was very interesting, as it showed that while what we see and what stories we ascribe to things are different, we're all still looking at the same sky."*

> *"People can lose out on job opportunities etc due to inherent bias. It is therefore essential people undergo training to eradicate bias as far as possible. For me, bias might affect my ability to get employment."*

> *"Social issues raised during this workshop is [sic] applicable to every person in our community."*

“Positive because we help nature”

“For me personally, could affect the idea to learn more about the city I live in and to find out more about the nature and sky that surrounds me”

“We are all affected”

“We could take better care of the environment”

(2) Enjoyment (of the process)

“I was really excited to learn how to makes zines as it was something I'd never done before”

“I’ve never done something similar to this.”

“The workshop was very different to the science-based learning that I’ve done before in school because it was more of a discussion than a class, which made it much more enjoyable as I felt everyone could share and contribute and have their opinions be heard.”

“It helps me reflect on covid 19 and it helps us take some time out and make cool stuff."

“In school we would just learn about space from a note-taking perspective, but we were able to get creative and more involved with learning in this workshop.”

“It's fun to play with robots and to learn more from them.”

“I participated in when we had to make a soundtrack It was really fun and funny! I enjoyed very much!!!”

“I really loved researching about Frida Kahlo. I learned a lot of things about her that I nerviest [sic] knew before.”

“I want this class so much, I want it to do it again! and I against my brother against my sister!”

(3) Personal Usefulness (of the content and process)

“Because this topic could be used in life”

“I think it can help you organise your thoughts with is very important in the current climate.”

“I think it’s a nice to know but unless I get a job in astronomy it won’t really help”

“There are new ideas in my head to build new things”

“It will help me finish school”

“I will be able to help my family”

> *"I will be able to get a job"*
>
> *"It will help me to become better in school classes and other students will not be making fun of me"*
>
> *"The topic interests me generally very because I want myself to do something with Multi Media in the future"*

These quotes demonstrate the diversity of learners' perceptions of relevance in each and every 'category'. This is particularly evident in the final selection of quotes that demonstrate 'usefulness'. While some learners felt that learning science will help them to support their families in the future, or excel in school in order to avoid bullying, others were interested to use the content for creative purposes, or for specific ideas they have about jobs or activities in the future. Similarly, there were students who recognise that perhaps the learning experience wasn't relevant for them due to its specificity in one particular subject area, which in itself is a helpful and important insight. The diversity of quotes shows that there is no one way to 'make science relevant' to learners, but that learners may experience an activity through any number of lenses that constructs a unique meaning for them.

2.4 How should science learning outside of school be recognised?

The final part of this section explores the findings of the project with regard to the use of credentialisation or accreditation within non-formal science learning. This work was identified as important because while the evidence of the broad diversity of science learning is clear, evidence of recognising and appreciating learners' engagements with and understandings of science is severely lacking.

As such, within WP 5, SySTEM 2020 trialled a credential that learners could self-award following their involvement in a SySTEM 2020 workshop associated with a self-evaluation or self-reflection activity. The credential could be awarded as a digital artefact or printed as a paper certificate. It was rolled out in three practice partner locations: Science Gallery Dublin, Kersnikova Institute, and Waag. Each partner could decide the award protocol, with Kersnikova and Waag awarding credentials based on the completion of an activity, while at Science Gallery the credentials were self-awarded by learners rather than via facilitators.

Interviews with learners who took part in a three-week internship programme at Science Gallery Dublin were asked about their opinions of the use of credentials alongside their experience. The response was varied, with most learners commenting on its usefulness for commemoration, potential use for applying to jobs, and noting that the points based state examination system in Ireland prevents its use in applying to university.

One learner felt that the credential would do “no harm” but that it might not be particularly useful. In other cases when this learner had received certificates, they felt that they hadn’t really used them.

Another learner felt that having a credential is “better than not having it. It shows that you’ve done something and you can show it off, even if it’s digital”. Though because of the points based entry system into higher education in Ireland, the only use would be for “a future employer and that kind of thing, or even just to have it as a memory”.

The third learner replied “I'm not sure if it'd be useful for me, but I think I'd like to have it to commemorate the program”, though after a bit more discussion about potentials for jobs or interviews, they felt that perhaps there was use in an accreditation system for the programme; “I think it could be useful though, to show initiative to do things outside of academics. It'd be a nice way to show how I spent my time.”

The final interviewee felt that they would like a credential and would use it for their CV. This student had the added relevance of applying for architecture at university, where they would be able to bring a portfolio to the interview and so potentially the accreditation could come in useful there.

The response from learners in Ireland was somewhat lukewarm, but credentials definitely were not met with opposition, though it is likely that these perceptions differ with context both within and between countries in Europe. The responses from Kersnikova and Waag were very similar in nature, where learners typically responded that they would keep the credential and show it to their friends and family, but wouldn’t imagine much further future use for it. Given that these learners were younger (9-12) than SGD’s learners (14-18), applying for academic programs or work did not yet seem a relevant a criterion for credentialled learners. However, similar to those from Science Gallery Dublin, they were not negative towards receiving it, but the motivation was more concerned with memorializing an experience among their immediate social environment, including family and friends.

Such interviews, alongside conversations among project partners have helped to highlight that creating a credential is only the first step, but creating an integrated informal and formal education system where that credential might be valued is the next crucial, and decidedly more difficult avenue to pursue.

3 Institutional perspectives on science learning and equity

This section addresses the question *How has SySTEM 2020 supported institutions and* educators *to support and further science learning in non-formal and informal contexts?*

From the initial stages of development of the SySTEM 2020 project, it was a core objective to promote equitable access to science learning for all young people across Europe. By gathering research results across 19 countries and working in collaboration with a group of international experts, as well as with young science learners, the consortium developed a number of resources which may support the educators and institutions who are working to deliver and facilitate science learning outside the classroom. In particular, **this section outlines the participatory approach taken in the development of these resources, and summarises the key messages for educators, and for decision-makers, funders and policy makers**. Finally, the section summarises some emergent trends from the current practices of organisations active in non-formal science learning in Europe, as mapped by the SySTEM 2020 project. This provides some insight into the areas of positive action towards equity, and identifies some gaps which would be interesting for future research.

3.2 Participatory Design Approach

The SySTEM 2020 approach to generating an understanding of diversity, equity and inclusion with relation to the field of non-formal science learning was to use a process of co-design, involving project partners and an External Expert Advisory Board, as well as other organisations and individuals active in science engagement research and practice, and in some cases, young learners. This approach began with an identification of the barriers to science engagement, and the development of strategies to support learning design. Finally, further consultations and workshops led to the development of institutional-level guidelines on equity.

Co-design builds on the tradition of user-centred design, and on approaches which advocate for relevant and usable design solutions through the active participation of the design beneficiaries (Durall et al., 2020a; Sanders & Stappers, 2008). The rationale for involving a range of stakeholders in a design process is based on the recognition that people are experts of their own experience (Sanders, 2002). Co-design is considered a valuable approach to support stakeholders' collaboration, ownership of design solutions and empowerment (Durall et al., 2020b).

Co-design activities can be oriented towards sharing experiences and collaborative sensemaking, as well as towards finding potential directions that can help in framing the design space. As part of the SySTEM 2020 project activities, a co-design event with project partners and stakeholders was organised on the 18th and 19th of March, 2019 in Helsinki. The aim of the meeting was to actively involve all participants to collaboratively explore and develop a shared understanding of the main challenges and opportunities to support science learning outside the classroom. The SySTEM 2020 project's direct stakeholders are organisations and groups connected to science learning, such as staff of science museums, makerspaces, libraries, but also individuals such as learners (whether they are currently involved in science learning or not), educators and facilitators. In total, there were 51 participants - this included 29 staff from the SySTEM 2020 project partner and third party organisations, 13 learners aged 18-20 invited by SySTEM 2020 project partners, and 9 "stakeholders" - individuals connected to formal or informal science learning but not explicitly connected to the project. These participants hailed from 19 countries in Europe and Israel.

It is important to acknowledge that inclusiveness and creativity are at the centre of co-design, rather than efficiency and effectiveness (Moser, 2016). In this sense, the process of co-designing solutions to challenges facing the community of non-formal science educators allowed the SySTEM 2020 project team to develop insights and create more generalised supports and guidelines, rather than aiming to create and implement functional solutions to specific challenges.

In advance of this co-design session, the design researchers leading WP4 carried out a contextual inquiry using a rapid ethnography approach. After a careful examination of the themes identified in this contextual inquiry, three main challenges in non-formal science learning were identified, discussed below.

1. **Barriers to access scientific culture.** At a systemic level, socio-cultural aspects pose significant barriers for some individuals to access science learning opportunities, and scientific culture more generally. 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.

2. **Challenges connected to learners' self- concepts**. Regardless of skill level, identifying oneself as a "science person" is key to access and participate in non-formal and informal science learning. Without a self-identity related to science, even the mere act of finding entry points to join pre-existing social groups or to set foot in the contexts in which these groups tend to engage, might be challenging. STEM activities might be considered as profoundly related to school culture and "nerdy", and thus, they might not be regarded as appealing or popular. STEM activities are "competing" with other free-time activities, such as sports, hanging out with friends or socialising 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. As inferred from observations and interviews conducted by SySTEM 2020 researchers in Finland, and consolidated by the SySTEM 2020 WP3 survey research, the dominant view of the culture of science is that it 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 (Achiam and Holmegaard, 2015; Archer et al., 2010; Ulriksen, 2009). The sum of aspects that play a role in people's exposure and knowledge about science has been defined as science capital (Archer et al., 2015), a relevant concept to understand how people relate to and engage with science learning. Yet, there is a difficulty in identifying what counts as science - 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.
3. **Challenges for sustaining interest in science learning**: Learners' ability to self-direct their learning about science topics is related to their ability to sustain their interest over time. While engaging certain groups in STEM is an initial challenge, a related universal challenge for non-formal STEM educators is the challenge to maintain that engagement over time, and ensure deeper learning and connection with the concepts and topics explored. The main challenges for sustaining

learners' interest seem to be connected with self-regulation and self-assessment. Supporting learners' ability to self- regulate is not often a primary goal in non-formal science education activities - less than half of the 1537 activities mapped by the SySTEM 2020 project list "learning to Learn" as a key competence addressed through the activity (Section 3.4). 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.

Three key thematic areas related to non-formal science learning were identified for further examination through the SySTEM 2020 co-design process, with the aim of addressing the challenges outlined above. These were:

- Inclusion
- Engagement
- Assessment & recognition of learning

The 51 participants were split into three groups, and given one topic each to work on over two days, scaffolded with a series of specially-designed supporting materials and processes, allowing them to understand & define their challenge, ideate solutions related to the challenges, democratically decide on priorities to bring forward, and to finally present a prototype solution to the entire group, as well as invited guests.

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; d) collaboration between different actors and entities.

These design solutions aimed to increase learner 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.

The design solutions for supporting **engagement** in science learning outside the classroom addressed challenges related to involving people, the relevance of science learning offerings for diverse groups, and the current 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.

These design solutions sought to improve science learning outside the classroom by making positive changes based on new and more exciting ways to teach, recognising 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.

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.

These design solutions supported participation, equality, freedom, well-being in order to increase learners' and educators' awareness on their actions, encourage sharing and transferability of experiences.

The full set of solutions, as well as the materials generated by the participants in the co-design sessions, recordings, and researchers' notes were compiled and analysed thematically to develop a set of insights related to each topic. The solutions developed all shared some elements of the following characteristics:

- Embracing diversity
- Adopting participatory approaches
- Leveraging readily available resources
- Building connections between formal and informal science learning
- Fostering risk-taking and learning from failure
- Supporting transversal competences / 21st century skills
- Acknowledging learners' achievements

3.3 Supporting Educators & Facilitators

The preceding subsection introduced the participatory design approach, the identified challenges and thematic areas for examination and the features of the resulting co-designed solutions. In this section, we present the key points of the design principles which were developed to support informal science educators in their practice, and reflect on the approach and results.

Design Principles and Methods Toolkit for Supporting Science Learning Outside the Classroom

The specific learnings that emerged from the participatory design sessions were further developed into the **SySTEM 2020 Design Principles and Methods Toolkit for Supporting Science Learning Outside the Classroom**, with the key insights distilled into the following three themes and subthemes:

Figure 2: SySTEM 2020 Design Principles and Methods Toolkit Themes and Subthemes

Reflections on the Development and Use of Design Principles

Collaborative design helps to include a diversity of voices and perspectives and cultivates equitable practices. While the participation of diverse science learning stakeholders helped to build a shared understanding of the challenges and opportunities that learners and educators face in non-formal science learning settings, the process was not exempt from tensions due to the stakeholders' different needs. During the development of the design principles, the adoption of a co-design approach helped to acknowledge these gaps and negotiate the solutions. The co-design process provided learning opportunities for SySTEM 2020 stakeholders and partners by showcasing tools and methods for collaborative design. As one of the partners expressed after the event in Helsinki: *"I have the impression that the co-design session has been a great chance, for a variety of people, to experiment, a deep moment of debate and reflection. Such… moments are particular for several reasons: the international breadth, the importance and the quality of the content presented and debated, the experience of the structured facilitation of such big groups"*. Since the co-design sessions in 2019, several partners have started using this approach within their own practices to foster diversity and inclusion.

The approach taken was to develop design principles that may be applicable and usable by a wide range of organisations active in non-formal science learning. There are **challenges inherent in adapting such broad and generalised tools** in any given context. They provide general guidance to inspire, but the intention is to be independent of learner demographics, pedagogical framework or learning design methodology. Section 4 of this report discusses how this was approached by two organisations within the SySTEM 2020 consortium (Science Gallery Dublin & Kersnikova Institute). The case of Science Gallery Dublin is also outlined as a proof-of-concept of applying the design principles in a forthcoming paper by Durall et al. (in press). In general, the design principles provide a grounding checklist, but there is a required process of translation as an important step that requires the active involvement of the educators who plan to use the tool.

Making progress towards equity in non-formal science education in a meaningful way requires **awareness of the complexity of the issue**. Inequity in science is reinforced when care is not paid by learning designers to think critically about who they are trying to engage, and who they are excluding (DeWitt & Archer, 2017; Dawson, 2014a; Dawson, 2014b). Individual educators must shoulder this responsibility, but the ultimate goal of advancing equity in science is a collective endeavour requiring effort across an organisation at all levels, and across the entire scientific community. The design principles should be understood as a modest part of this shared effort.

3.4 Attending to Equity at the Institutional or Organisational Level

The analysis carried out by the SySTEM 2020 research team through contextual inquiry, co-design and expert consultations in relation to issues of equity in science learning highlighted inequity as a systematic issue which must be tackled at a number of different entry points, by multiple complementary actors. Science education is one part of a wider societal system which interacts with the broader education landscape, as well as with the ecosystem of science research, innovation and industry. There are inherent structures of inequality at play, which pose multiple intersectional barriers and which perpetuate systems of power and control (Dawson, 2018).

While the **Design Principles and Methods Toolkit for Supporting Science Learning Outside the Classroom** (D4.2) targets educators and programme managers working directly with young science learners, the **SySTEM 2020 *White Paper on Equity-Focused Science Education Outside the Classroom*** (D4.3) targets a different part of this system and is aimed at decision-makers within science learning organisations or institutions, as well as policy-makers and funders. The document provides a holistic view of the major issues identified, and provides structured guidance and support across a number of key action areas, collaboratively identified and defined with the expert consultant stakeholders:

Action approach	Strategy
Framing	Incorporate equity into the organisation’s values, vision and mission statements, as well as into the strategic plan.
	Involve the organisation’s board and staff in the definition of strategies at all levels.
	Include diverse stakeholders in decision-making processes.
Embedding	Bring diversity into the organisation.
	Form committees and working groups to steer work around equity.

	Make conversations around equity part of the institutional culture.
Bridging	Create welcoming environments.
	Strengthen the collaboration with formal education.
	Develop partnerships with societal actors from minority groups in science education.
Involving	Recognise the assets of the communities who do not engage in the activities offered at your organisation.
	Engage with a diversity of stakeholders.
	Support participation from the ideation to the assessment of programmes and initiatives.
Designing	Broaden the range of literacies in informal science education.
	Build on culturally responsive pedagogy.
	Support educators' and learners' critical agency.
Assessing	Develop a holistic approach to evaluation.
	Monitor progress towards the organisation's goals around equity.
	Use multiple methods to collect evidence for equity.
Sustaining	Seek funding to support the organisation's work on equity.
	Provide ongoing training on equity for staff and board members.
	Foster a diverse community through growth paths.
Advocating	Make the commitment to equity explicit.
	Raise awareness around the importance of equity in informal science education.
	Think big and work towards a desirable future.

Table 2: Action Areas in the SySTEM 2020 Whitepaper on Equity-Focused Science Education Outside the Classroom

In summary, the key messages are:

1. To have impact, work towards equity should also consider the organisation's mission, values as well as all organisational processes.
2. Equity is the result of a community endeavour and needs to be based on collaboration with diverse societal actors. Thus, **bridging** different environments and **involving** multiple stakeholders connected to science learning should be a priority.
3. Pedagogical practices in science education need to be reviewed from an equity perspective. This has strong implications for **designing** science learning programmes and activities. The SySTEM 2020 Design Principles and Methods Toolkit can be useful in this regard.
4. Supporting equity requires iteration and perseverance. Thus, **assessing** and **sustaining** equity-focused actions should be regarded as integral in informal science education organisations.
5. Committing to equity demands thinking beyond a single organisation and actively working to dismantle the conditions that create inequalities in informal science education and society. This means that **advocating** for equity needs to be integrated into an organisation's activity.

3.5 Existing promising practices identified by SySTEM 2020

While working together from the point of view of overcoming challenges and obstacles in relation to equity in science learning, the SySTEM 2020 project also identified a number of existing good practices, and generated a wide-ranging map of the landscape of informal science learning across Europe and Israel[16]. As of May 2021, there are 1451 organisations offering 1537 different non-formal learning activities in 25 countries shown on this map. Map entries contain a wealth of information about an organisation - the cost to participate or to enter, the age range catered for, the specific topics covered, whether the activities incorporate the arts, and whether the organisation collaborates with formal education. Anyone can download the data from the map and use it for further research. The SySTEM 2020 consortium members have strengthened links with organisations in their respective countries and regions through the campaigning process and the increased visibility of links between organisations, which is one of the online visualisation options available.

[16] https://system2020.education/the-map/.

This section contains some visualisations of this data. The response categories were generated by the SySTEM 2020 research team based on user consultations with a sample of stakeholders. Respondents may leave these sections blank if none of the options are suitable for describing their programmes.

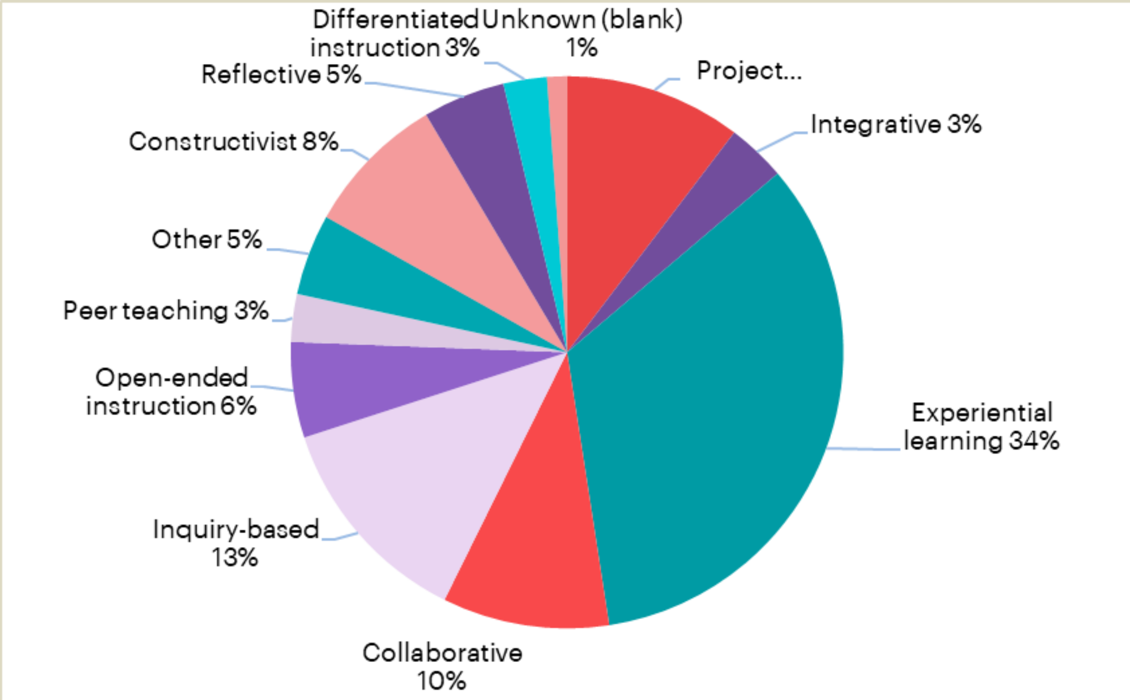

Figure 3: Activities listed on the SySTEM 2020 map categorised by pedagogical approach (n = 1537)

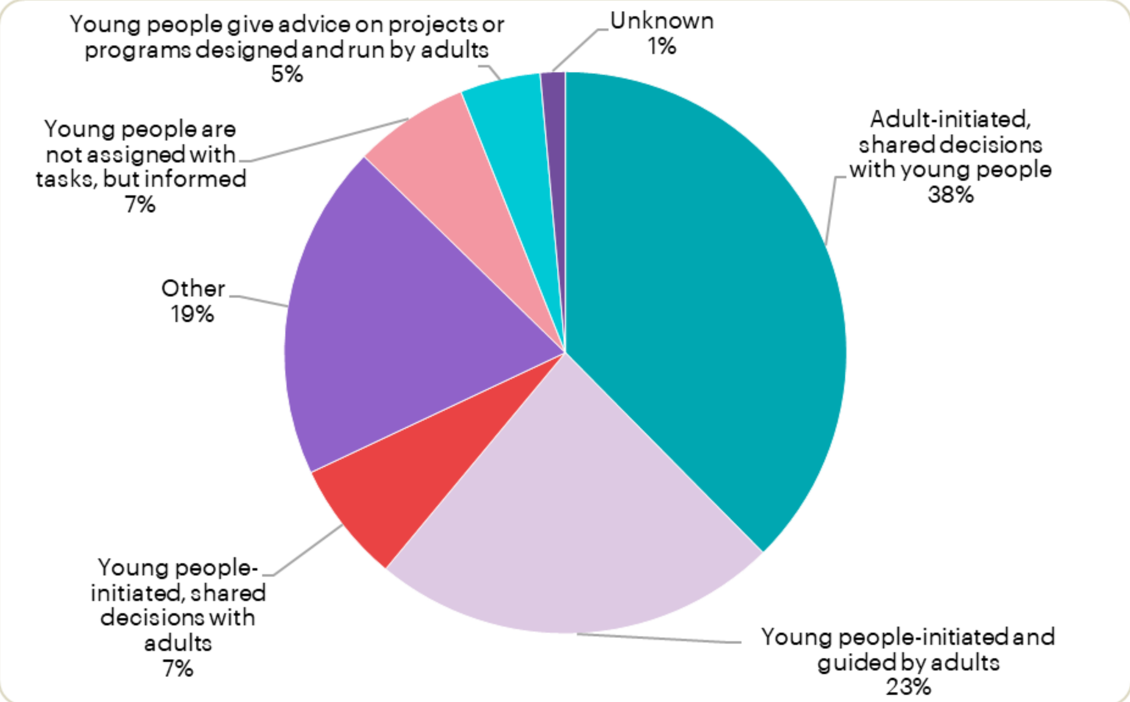

Figure 4: Activities listed on the SySTEM 2020 map categorised by decision-making process (n = 1537)

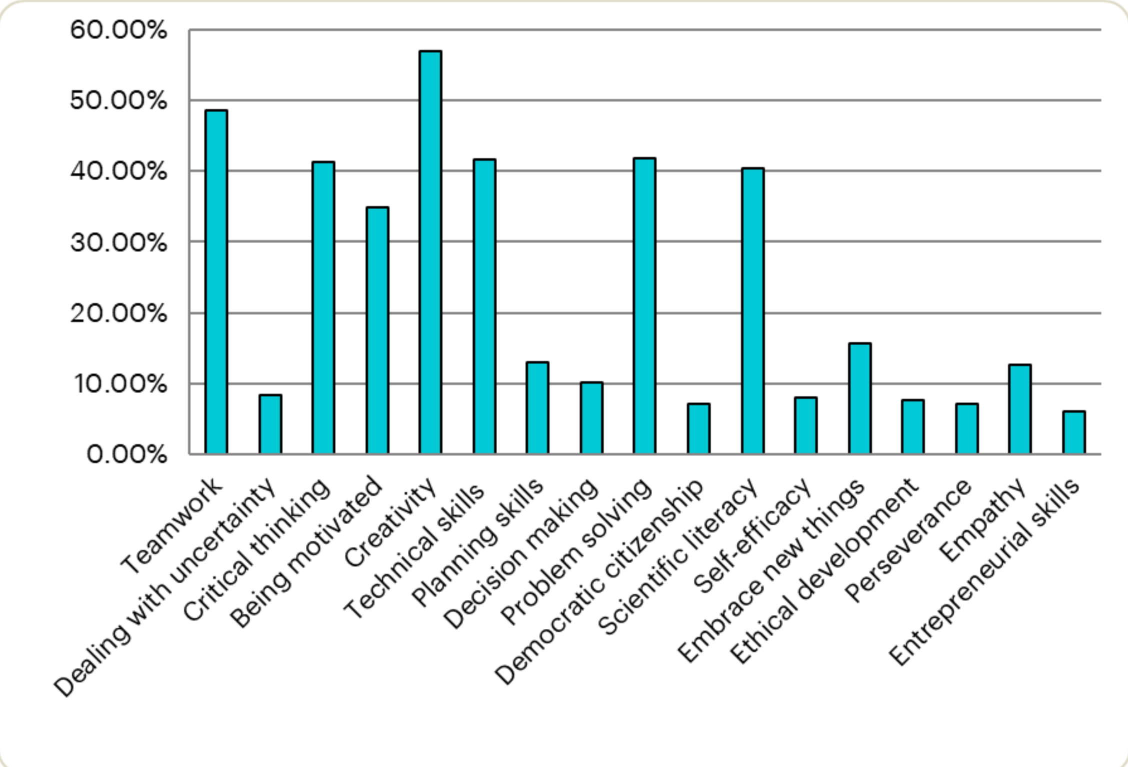

Figure 5: 21st century skills addressed (frequency, n = 1537). An activity may address more than one skill.

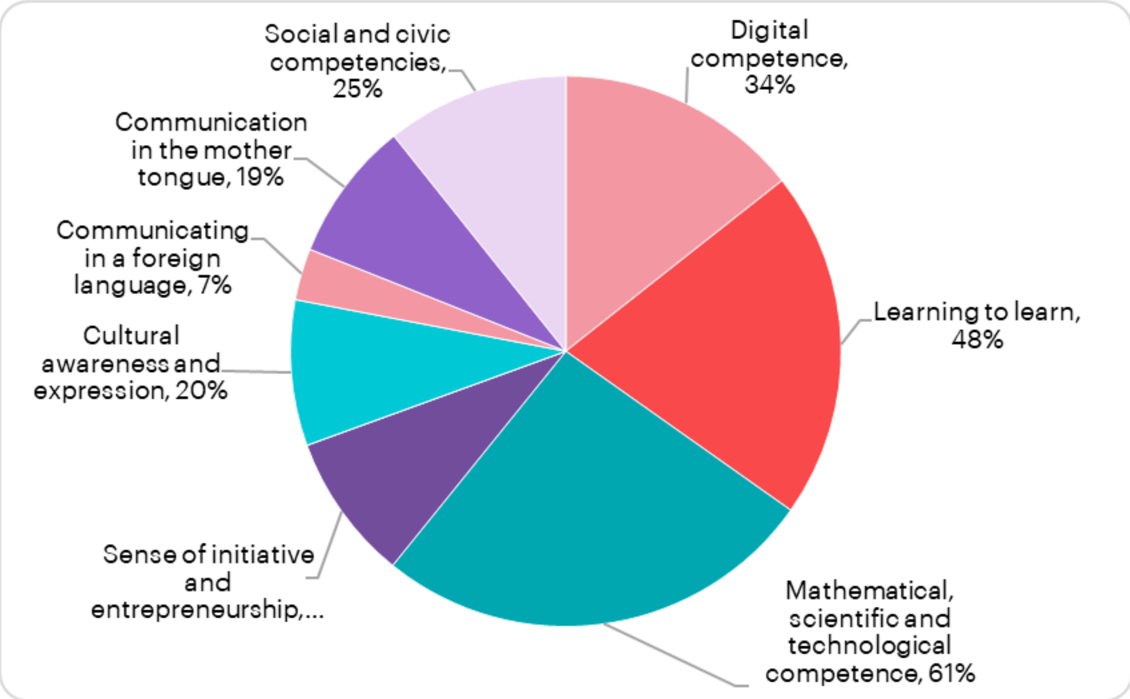

Figure 6: Key competences for lifelong learning addressed (frequency, n = 1537). An activity may address more than one key competence.

STEAM (science, technology, engineering, the arts, and mathematics) approaches are used by the majority of the SySTEM 2020 partners and are strongly promoted throughout the project. The growing popularity of STEAM learning is evidenced in the fact that the arts (including theatre or music) are featured in approximately one-fifth of activities on the map (300 / 1537). However, at the organisational level, the SySTEM 2020 map is overwhelmingly multi-disciplinary, with only 171 of 1451 organisations (12%) NOT listed as engaging in one or more of the following combined STEAM topics:

- Community work
- Crafts
- Design
- Citizen Science
- Music
- Construction
- Nature study/Preservation
- Gardening
- Agriculture
- Sports
- Performing arts
- Video/film
- Visual arts
- Cooking
- Home Economics

4 Assessment of project impact

The research questions above have helped to build an understanding of the SySTEM 2020 project's findings and contextualise these within the areas of research and practice specified in the objectives. In this section, the results of the project activity as a whole will be considered in order to understand the ways that SySTEM 2020 has, and will continue to, impact its surroundings in terms of individuals, communities and societies.

The section is framed around answering the following question:

What has the impact of this project been at individual, institutional and community levels?

This section of the report will explore lasting impacts in each realm as shown in Figure 7, below; from individual learners, to institutional and professional practices, and the wider context of communities, cultures, and the field in which the project sits. At each of these levels, this report will consider quantitative indicators of the project's contributions, as well as situated case studies which demonstrate qualitatively how such activity can deeply impact those in and around the work. Finally, reflections on how these findings fall across social, economic, political and technical realms are used to demonstrate the diversity of levels in which SySTEM 2020 has impact, alongside the transdisciplinary and thus necessarily societal nature of these impacts.

Figure 7 helps to frame this section of the report. Learners' experiences, feelings and competencies are focal to the impacts of the SySTEM 2020 project, but these impacts are further reinforced by, and cannot be separated from institutional change, and wider supportive structures between and within institutions, which are considered as the concentric circles expand.

Findings for this section of the report have been collected via surveys and semi-structured interviews. Both third parties and project partners completed a quantitative survey which reported on numbers of learners, staff and stakeholders engaged, alongside audience numbers for activities delivered as part of SySTEM 2020. Further to this, third parties completed a qualitative questionnaire which they used to reflect on the most useful tools and outcomes from the project, as well as any specific stories of success that they felt came out of the project. Partners undertook interviews with key stakeholders (within and/or beyond their institutions) to gather evidence of impacts in their context, these were written into small reports. These reports and qualitative survey responses were used for the case studies used to demonstrate impact at each of the levels below.

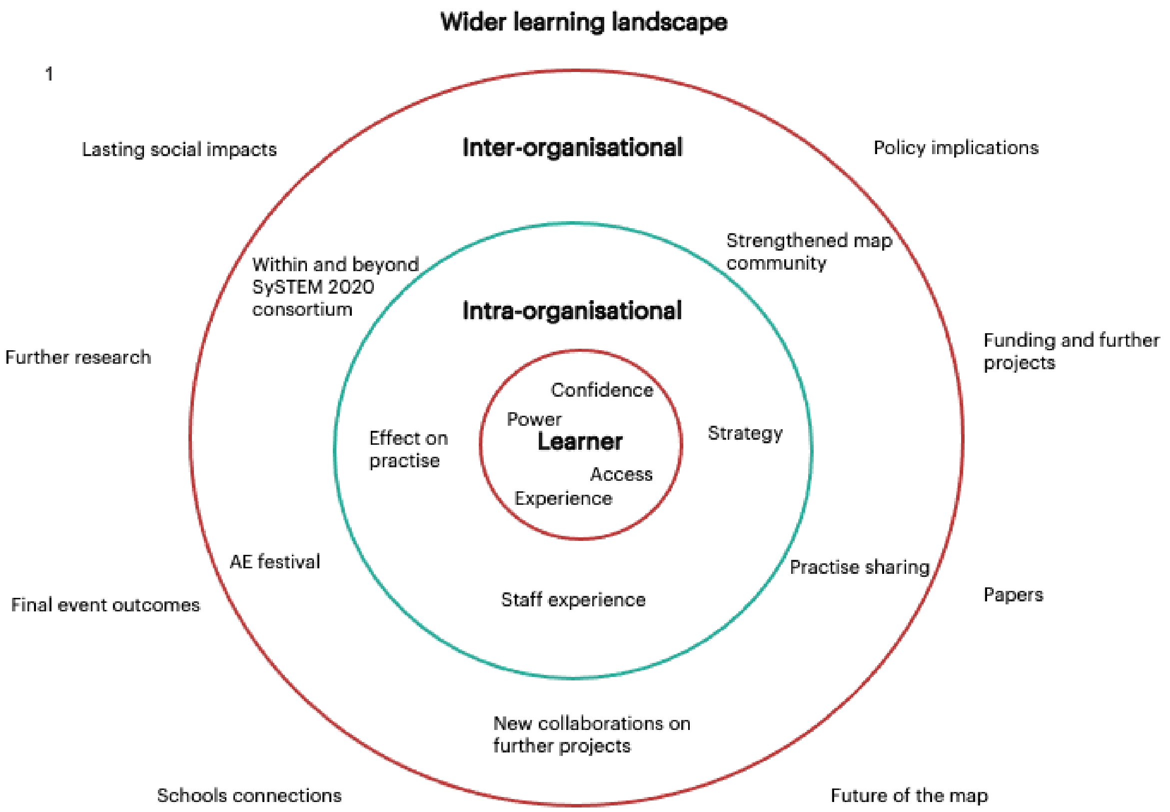

Figure 7: Levels (and examples) of potential project impact

4.1 Lasting change in learners

This section explores the core of intended impact - the lasting change on learners themselves in terms of feelings, experiences, skills, knowledge and competencies.

Top Line

Over the course of the project, SySTEM 2020 has engaged over 4000[17] learners in over 170 workshops, activities and programmes. The key findings of this section are that SySTEM 2020 supported an increase in access and inclusion to workshops in consortium member organisations, such that more learners were able to be reached, but most importantly, these learners might not have been the typical audience of the institution previously. Increasing access is the first step in enabling lasting impact on behalf of diverse learners, but going further than this through the activities themselves is

[17] This number differs to the number listed in the Final Report because it is not restricted to learners who participated in the project research, but all learners whose visits/experiences have somehow been funded/contributed to/ supported by the SySTEM 2020 project.

necessary. This is demonstrated in Parque de las Ciencias, where the organisation felt supported to tailor activities to learners. The tool specific case study which looks at the learning portfolios goes on to demonstrate that meaningful participation is crucial to learners' enjoyment and continued participation in projects such as SySTEM 2020.

Third party case study: Parque de las Ciencias, Spain

Title: Widening audience diversity

Parque de las Ciencias are a third party on the SySTEM 2020 project, and as such, took part in the map campaign, the longitudinal survey and the development of the Design Principles. As part of their project activity, Parque de las Ciencias welcomed an additional **190 underprivileged young people**, who are distinct from the typical audience of their non-formal science learning institution. The project was an important factor in facilitating these learners' experiences at Parque de las Ciencias, since the tools and support meant that Parque de las Ciencias staff felt "it reinforced our work in inclusive science education". Importantly, rather than just invite these learners, **the team were able to adapt their practice to better serve them within their institution**, "we are more aware of the importance to collaborate with different stakeholders to draw an inclusive and equal informal science education... it has helped rethink the way of organising activities more [to] focus on looking to engage underprivileged public". While it is important that the institutional practice was able to develop in this way, it also means that the learners who took part in SySTEM 2020 activity not only experienced something they might not have been able to without the project, but that the experience was more tailored to their needs as a result of the project's support. The facilitators who worked with these young people saw benefits to learners beyond the workshop content and activity themselves, as they mention that the **science capital survey helped learners "to think about their link with science** and the importance of their parents, teachers and friends for connecting with STEAM subjects".

Practice partner case study: Ars Electronica, Austria

Title: Offering long term opportunities to local youth groups

Ars Electronica are a project practice partner and used their involvement in the project as an opportunity to engage youth groups in long term free opportunities that contributed to the SySTEM 2020 project via testing and using the tools. Ars Electronica worked with under-represented audiences from local childrens' centres and youth clubs, who are less likely to visit the institution on a regular basis. By continuing to work with this youth group throughout the course of the project Ars Electronica were able to gain an insight into the longer term impacts of science learning on these young people. The youth centre they worked with engages children and young people from non-privileged backgrounds, for many of the participants it was the first visit to Ars Electronica. The fact that the workshop and tours were free of charge broke down one of the main barriers, according to their social worker. To explore these impacts, Ars Electronica interviewed children, their parents and social workers about the effect of the project on the audience to form this case study.

Through the interviews, they found that the young people recognised the unique learning opportunity of the workshops, whereby they **"weren't just fun and games" but they also were "different from being at school**" due to their hands-on trial and error approach. A mother of one of the workshop participants noted that there was no pressure to perform, which she believed led to a free, playful and fun learning experience as well as a feeling of team collaboration among the participants. The young people's social worker noted that the experience seemed to facilitate exploration from the learners, even those who do so less typically; **"I was surprised that the girls loved to try things first-hand, usually they are more hesitant."** She also explained that the financial barrier meant that without this opportunity being free, her youth group would be prevented from participating, as they are with many other cultural and educational activities. The experience led to meaningful and continued involvement with the participants, one of the interviewee learners planned to come back to Ars Electronica in the future, and **during the interview realised that he "is qualified to submit for the Prix Ars Electronica u19" so made plans to do so.**

Tool-specific case study: Learning Portfolios

LATRA, Greece & Tom Tits, Sweden

This tool-focussed case study explores the experience of two organisations (one third party and one practice partner) with the learning portfolio zine tool, an output of the project in which learner experience and empowerment was of utmost importance and consideration.

LATRA had a particularly successful pilot of the learning portfolio zine tool in their practice partner institution, which they rolled out with 10 learners for the purpose of the SySTEM 2020 project, and have continued to use in other activities beyond the project.

One of LATRA's impact interviews was with a young person, aged 17 from Afghanistan who had been engaged in the project for 3 years and took part in the zine making activity. It demonstrates the power of a learner-led participatory tool in reinforcing learning experiences and positive personal impact. In particular, this learner felt that the tasks **which invited them to meaningfully reflect were enjoyable and participatory**. In the past, their experience of evaluation was top-down and less creative, both in school and in non-formal education. The hands-on nature of the zine as a self-reflective learning portfolio that contributed to research was novel to them; through the interview process the learner shared that prior to SySTEM 2020 they had had a negative experience of research projects, which required passive participation and thus lacked personal meaning and relevance. As a result of their experience with SySTEM 2020, **the learner shared that, "I now trust in myself more... I am more confident to share my opinion",** and even that the project and related activities, such as the zine tool helped **"relationships with facilitators and sometimes my flatmates"**. In reflecting on the aspects of the project and tools that enabled this impact on their learners, LATRA noted **"the overall impact lies in the way the activities were structured and conducted, allowing learners to self-reflect and self-evaluate the activities for which the vast majority was a new experience. This in turn allowed their confidence, self-esteem and trust in their abilities to grow."**

Tom Tits in Sweden, as a third party, were not required to use the learning portfolio tool as part of their activity in the project, but opted to adapt and use the zine tool in their context nonetheless. They found the tool particularly useful as they previously lacked a tool that is participant-focused and encourages participants to reflect in a non-formal way. Tom Tits reflects that "there are many benefits to using the Zine as a reflection tool. It is a simple material that engages the participant quickly and unpretentiously. It is also something that can be used in many age categories and regardless of language level". They note that the zine supports learning beyond the experience as well, enabling the learner to continue engaging and reflecting after their interaction - **"The zine becomes a material that the participant can take home so that the conversations about the experiences can continue at home, and thus extend the activity."**

Alongside the other two case studies on learner experience and impact, the use of the zine/learning portfolio tool helps to demonstrate that the purposeful design of tools which prioritise learner experience are a central part of SySTEM 2020 project and crucial in facilitating long lasting, empowering and meaningful change in learners themselves.

4.2 Lasting change in SySTEM 2020 consortium organisations

This section explores the deep impacts on the SySTEM 2020 consortium organisations, who each had individual and varied experiences as project partners, third parties, work package leaders, and members of working groups to further specific project aims. Interest here lies in lasting organisational change, but also personal reflections on the effect of the project on collaborators and teams.

Top Line

From the beginning of the project until 30th March 2021, the SySTEM 2020 project consortium (consisting of 11 partners and 11 third parties) has been directly contributed to by 61 professionals within those organisations, and indirectly with a further 120. The wide number of collaborators on the project means that there are many opportunities for the project to impact internal practices in a lasting way, which are shared below.

The key findings of this section are that SySTEM 2020 findings and tools are of use personally for organisation staff and strategically for future organisational direction. EMBL's case study exemplifies that talking through the findings can influence strategy and practice, and will also continue to be considered in more informal contexts on a personal level. At Kersnikova, project tools are being tweaked and employed to serve the institution in the future. The Design Principles are isolated as a particularly useful tool that provides guidance and support to institutions and has already had, and will continue, to impact SySTEM 2020 organisations as shown by the numerous examples below.

Third party case study: EMBL, Germany

Title: Communicating SySTEM 2020 findings to colleagues and peers

As a third partner, EMBL took part in the co-design workshop in Helsinki and the consortium meeting in Belgrade, campaigned for the SySTEM 2020 map, gave feedback on the design principles and carried out the longitudinal survey with their learners. They also joined the working group for the Ecsite preconference work in 2021 and helped to design and deliver sessions on imagining the future of equity in science learning. Third parties are continually involved in the project through sharing emerging plans, findings and conclusions, and are invited to use and adapt resources for their own purposes as much as possible. It is clear that in EMBL, the learnings from SySTEM 2020 have been adopted and used for the purpose of that organisation in a positive way. Rather than prescriptively using tools, they discussed and considered ways in which the learning from the project can be embedded in their organisation in more subtle and intrinsic ways.

"As the project manager I give our team (which includes a teacher, education managers and interns) regular updates about the progress of the entire project. This included a comprehensive two-part presentation covering the evaluation framework and methodology, before sharing the preliminary findings, recommendations and conclusions. **This generated extensive insights into our work: our cohorts, practices and ideas for future projects.** The resulting discussions as a direct result of these presentations lasted for hours going well over the designated time period and **we continue to reference them months after I shared the key findings from SySTEM 2020"**.

The change at EMBL is not just organisational, but also individual; the SySTEM 2020 project manager shares **"I personally have learnt a lot and will continue to discuss the findings and tools beyond the scope of the project... both informally and formally"**. Lasting change on the part of professional individuals and organisations also reinforces the benefits and impacts on young people, since EMBL have reinforced the lasting change by embedding practices further into their practice. The SySTEM 2020 project manager has since created two co-design workshops which are used to develop laboratory-based protocols collectively for young learners, based on the co-design tools and project approaches.

Practice partner case study: Kersnikova, Slovenia

Title: Embedding SySTEM 2020 tools into practice

As a practice partner, Kersnikova has had first-hand experience with all of the project tools; including the longitudinal survey, the ESM, the self-reflection and self-evaluation tools, zines, the observation mapper, the map and the design principles. The SySTEM 2020 project manager at KI notes that **"we always try to learn from the projects we are participating in...** trying to include new tools, new knowledge into our programme. **From the SySTEM 2020 project some really useful tools came out... we are going to use them all in our future activities".**

In their impact assessment interviews, Kersnikova drew on opinions from their team including the Head of Educational Programmes, the Head of Facilitators and Facilitator at biotech lab Biotehna, the Lead Facilitator of Rampalab, and another facilitator/mentor within the organisation. Outside of their team, they interviewed the coordinator and facilitator at each of two partner organisations (Zavid Slmetris and ZPM Moste) who worked with KI within the SySTEM 2020 project.

In particular, the Design Principles were identified as a tool which will continue to influence practice following the end of the project, beginning by shaping this year's educational program at Kersnikova, and forming the backbone of their facilitator training going forwards. Kersnikova also published the design principles as a condensed handout, which provides their partner organisations ZPM Moste and Slmetris, with a structured, systematic, applicable resource for workshop development in their own institutions. All the interviewees note how further organisations could apply and profit from the design principles in their work. The following quote from Kersnikova demonstrates the strength of the facilitator training based on the toolkit; "**The Design Principles, developed in the SySTEM project, are already shaping the 2021 program for training new facilitators/mentors and are going to shape the future ones as well.** With the design principles clearly defined, new facilitators/mentors now have an opportunity to better reflect on what their job is and why such approaches are important to their work". What's more, the existing facilitators are enjoying the process of adapting the toolkit into a training programme, as a mentor and facilitator expressed - "I wish the participants profited just as much from the design principles, as I did designing the workshop about them".

The Design Principles are not the only tool which will continue to affect work in Kersnikova, the SySTEM 2020 research that was conducted via the longitudinal survey has provided some important areas to consider which will make up Kersnikova's future evaluative framework. **The factors considered in the science capital survey provide an "in depth and comprehensive view of the areas of improvement, and an important insight into the challenges and progress of individual attendees of the workshops"**, though Kersnikova notes that they will adapt the survey to make it more playful and interactive for learners. The Head of Education at Kersnikova summarised their experience as part of SySTEM 2020 as follows; "As an organisation we have gained in-depth knowledge and we developed a great framework for evaluating our work, which is already informing our future work."

This case study shows how multiple aspects of the project are already feeding into the current and future practice of Kersnikova before the project has even ended. This gives a great indication of how impact will continue to grow in Kersnikova and their linked organisations, as well as indicating the ways in which other project partners or third parties could use and apply the project tools and methods.

Tool impact success story: Design Principles

The Design principles are a recent output of the project (produced in October 2020); they are institutionally focused and were co-designed by the consortium, which has led to them having lasting use and impact across and beyond all project partners and third parties. In this section, the Design Principles and their universal usefulness are briefly explored. When asked what was the most useful tool that came out of the project, Thessaloniki, Technopolis, Fundação da Juventude and TRACES all chose the Design Principles:

"No doubt, the design principles document. They have been already overtly discussed with the team that designs and facilitates educational programs in our organization" - Thessaloniki

"Design principles: My colleague also had the idea to laser some quotes from the design principles tool and hang them up in our Atelier. So that visitors are also inspired" - Technopolis

"We already apply many of the things in the design principles tool unconsciously, but we are not consciously working on them enough. SYSTEM 2020 has brought this to our attention." - Technopolis

"Many of the [event] participants expressed interest in getting the final version [of the design principles]. So besides the impact that the event itself might have had... they had the opportunity to discuss how having a set of 'design principles' can be valuable for planning new activities and programs". - Aalto on sharing the Design Principles beyond the consortium

Muzeiko and Kersnikova have formalised the toolkit into their institutional practice by developing their own training programme for facilitators and educators guided by the Design Principles and Methods toolkit. As well as resulting in long lasting and embedded impacts in the institution itself, this will develop a practice of equity in emerging science learning practitioners who will go on to shape the learning landscape in the future.

"The Design Principles Toolkit deepened our reflection and awareness as regards designing future programmes and activities, and also reviewing the current ones". - Muzeiko

"We have already developed a workshop based on design principles that it’s going to be included in our yearly facilitators training". – Kersnikova

The identification of the Design Principles by partners and third parties as a useful tool that encourages critical reflection on practice demonstrates the lasting impact that this tool is likely to have on all consortium institutions. The impact is unlikely to stop in consortium organisations, and through training, networking and dissemination via the SySTEM 2020 map the Design Principles and Methods Toolkit will continue to positively influence reflective practice in science learning.

4.3 Lasting change in organisations beyond SySTEM 2020

This section explores how tools, methods and approaches within the project have been able to support changes in organisations who are not a part of the consortium, but who have pre-existing or emerging links with SySTEM 2020.

Top Line

The SySTEM 2020 project consortium has directly engaged with over 700 professionals across Europe within and beyond SySTEM 2020 organisations through 18 webinars and 5 meetings with policy makers. The key findings of this section demonstrate that SySTEM 2020 has influenced and supported organisations beyond the consortium to deliver meaningful learning experiences. Both of the case studies below demonstrate how SySTEM 2020 organisations were able to use project tools and approaches to train, influence or contribute to activity in external science learning organisations within their countries. In addition, the SySTEM 2020 map is a powerful tool to foster relationships with other organisations in the science learning community and seed future practice sharing and collaborations.

Third party partner case study: Muzeiko, Bulgaria

Title: Collaborating with a newly emerging science centre

Muzeiko are a third party within the project based in Bulgaria. They took part in the Helsinki co-design meeting, the SySTEM 2020 map campaign, the longitudinal survey and the Design Principles Feedback. Muzeiko is the first and (hitherto) only children's science centre in Bulgaria, and are regarded with a high reputation. As a result of this, the museum staff were invited to consult the concept and creation of PlanetUm, a newly opened science centre in the seaside city of Burgas, coordinated by the municipality and funded by Shell. Burgas and Shell contacted Muzeiko in 2018 to request their assistance, consultation, and training as the new museum opened. One of the key aspects of the two centres working together was staff training, which took place in August 2020 in preparation for opening on 1st November that year (the Day of the Enlighteners in

Bulgaria). The training that Muzeiko ran for PlanetUm was based around two pillars, one being the presentation and facilitation of scientific content in accessible and engaging ways for diverse audiences, and the other being practical and logistical organisation of such an institution. Muzeiko used the Design Principles and Methods Toolkit to frame their training specifically around ensuring content is accessible and engaging for audiences. Thanks to the training, Muzeiko and PlanetUm plan to continue working together as collaborators, though this is currently an informal arrangement there is an important seed for future work between science centres across Bulgaria.

Practice partner case study: CPN, Serbia

Title: Taking Science Learning to Isolated Neighbourhoods

Practice partner CPN are based in the capital city of Serbia, Belgrade, and used the SySTEM 2020 project as an opportunity to share their approach to science learning outside their normal contexts so as to engage further organisations, and audiences, in approaches to informal and non-formal science learning. CPN's science camps are part of their annual programme, and take place primarily at CPN's makerlab in Belgrade. Due to this location, many participants are necessarily from the city and nearby neighbourhoods, which ring fences these experiences within the capital. With the support of SySTEM 2020, **CPN took the chance to leave the "dominantly privileged context of the capital city and enter communities in small towns in Serbia**". CPN used their network of 'science clubs' (diverse science learning organisations) across Serbia to host their science camps outside of the capital. In doing so, CPN was able to engage with learners and organisations outside of their normal remit, who in turn were able to learn from and adopt CPN and SySTEM 2020 learning approaches.

CPN explored the impact of these workshops by triangulating interviews with workshop facilitators, stakeholders and participants themselves. They found that the experience of working on the open ended maker projects that embrace STEAM multidisciplinarity proved to be very fruitful and was a huge learning experience for all parties involved: children, facilitators, colleagues from science clubs and their own institution alike. CPN explains that their "main goal was to support the development of the science communication skills for the people working at science clubs", which was met very successfully. After the last camp was finished, "all of the Science clubs involved expressed will to organize more similar activities. Some of them expressed readiness to do that completely autonomously".

This case study demonstrates an example of a SySTEM 2020 consortium organisation using the project to further the learning of other organisations beyond the consortium,

resulting in changes of practice which will result in learners in more diverse locations being able to engage with STEAM learning.

Tool impact success story: The SySTEM 2020 Map

By its very nature, the SySTEM 2020 Map involves organisations beyond the consortium and builds links with these organisations through the campaigning process and the increased visibility of crossover activities and/or priorities. The map was identified as a very useful tool by almost all of the third parties, with the quotes below demonstrating the ways in which this has furthered their connections and collaborations with organisations beyond their own.

"Through the map we discovered that we were working on similar topics with a Department in the university of the Aegean in Lesvos and we are currently pursuing a partnership to apply for EC funding through various programmes (H2020, Erasmus+, etc)" - LATRA

"The mapping activities for Bulgaria gave us an opportunity to get in touch and/or renew and refresh our liaisons with a lot of non-formal education providers". - Muzeiko

"We used the map for advocacy and raising our organisation's profile. Whilst advocating for the map, we came in contact with 50+ organisations in Greece and we believe that this helped us in raising the profile of our organisation amongst our peers". - LATRA

"The project made a map of non-formal learning in Europe that builds knowledge with and for society". - Kersnikova

"Through working on the map, we gained a much clearer view of the STEAM landscape in Switzerland and, to some extent, in Europe and the different ways in which STEAM learning outside school takes place". - Raumschiff

These quotes demonstrate the real usefulness of a visualised informal learning science community and begin to illuminate the possibilities that this supports - from practice sharing to networking and seeding future project potentials. Without the map the chance of the project to engage with and influence the wider informal learning landscape would have been much reduced. Further to this, Ecsite interviewed the company who created the map integration into the website, Infotude, who found the experience a learning process that will contribute to their future technological ability and creativity.

"It was definitely an intriguing and challenging project, I am really happy, I had not opened up the map in quite a while and it is great to see the amount of content on the map. Something I will dig into further now after this interview". – Infotude

4.4 Lasting change in the wider science learning community

Finally, in this section, the focus is the slightly less tangible wider science learning community. While there is no easy way to define this, the examples below draw on how aspects of the SySTEM 2020 project might have contributed to, become a part of, or influenced approaches to science learning in and around the non-formal institutions that make up our consortium.

Top Line

The project has supported 17 conference attendances, produced 4 peer reviewed publications and has one article in review to date[18], as well as resulting in at least 5 future potential project proposals.

In this section, two in depth case studies demonstrate organisations impacting their communities nationally and internationally via their reputation and expertise resulting from the SySTEM 2020 project. Both organisations have been able to influence future practice and contribute to wider research aims.

Third party partner: Tom Tits, Sweden

Title: Sharing Learning Research Nationwide

As a third party, Tom Tits in Sweden has been involved in the Helsinki Co-design workshop, the map campaign, the longitudinal survey roll-out, the consortium meeting in Belgrade, the equity workshops and the process of design principles feedback and compilation.

As a result of their involvement in the project, **Tom Tits has been given an increased role as a driving force in issues around research-based informal learning in Sweden, by The National Centre for Science and Technology Didactics (NATDID)**. NATDID works to support school development at the national level in science and technology by disseminating results from current research to those who are active in learning. While Tom Tits Experiment does not have the opportunity to conduct its own research, SySTEM 2020 gave them the opportunity to collaborate on and disseminate the results of the project to the universities that conduct education in learning. During the project period, while Tom Tits was active in disseminating results through NATDID, the Royal Swedish

[18] See Appendix.

Academy of Engineering Sciences (IVA) in Stockholm started a network for actors in the informal learning sector that offers activities to schools and general visitors. **"Thanks to work with Science capital and SySTEM 2020, we have been a natural member in this",** says Tom Tits' SySTEM 2020 Project Manager. As a result of their involvement in SySTEM 2020 and their collaboration in large scale research-practice dissemination, one of Tom Tits' largest funders has written in their agreement that the organisation **"will continue to work to spread knowledge about research and scientific methods to increase the scientific capital of children, young people and adults".** This example makes clear that the supportive and open structure of SySTEM 2020 has meant that an organisation is able to transform its national reputation as a communicator of research and practice, by contributing to, understanding, and sharing findings from a European-wide project. This work is done by Tom Tits through continuing education activities as well as in information campaigns in digital channels.

Practice & research partner: Science Gallery Dublin, Ireland

Science Gallery Dublin is the Coordinator of SySTEM 2020 and a project partner on many other funded projects including OS Hub[19], SISCODE[20], Space EU[21], STEM Inside[22], and INTEGRITY[23], as well as the first member of the growing Science Gallery Global Network[24]. As a result of this, the organisation is uniquely positioned as influential in contexts beyond the SySTEM 2020 project and consortium. There are a few key examples where SySTEM 2020 approaches, methods and tools have gone on to play a part in further European projects, national initiatives and international science learning practice, as detailed below.

Title: Design Principles and Diversity Equity and Inclusion

It is clear from the impact case studies above that the Design Principles and Methods Toolkit, developed by Aalto, has been hugely influential in terms of impact within and beyond the SySTEM 2020 project. In particular, Science Gallery Dublin and its unique position as a contributor on myriad further projects has meant that the Toolkit and its underlying principles have already been used to embed equitable practice into further non-formal science learning projects, institutions and activities. In particular, the Design

[19] https://oshub.network/
[20] https://siscodeproject.eu/
[21] https://www.space-eu.org/
[22] https://education.uw.edu/news/stem-inside-arts-integrated-stem-learning-programs
[23] https://h2020integrity.eu/
[24] https://sciencegallery.org/

Principles and Methods Toolkit was used to refine and develop Science Gallery Dublin's OS Hub curriculum activity, whereby the Open Science Coordinator and the Informal Education Researcher used the principles as an opportunity to "check" aspects of the accessibility, diversity and inclusion of their programme. When reflecting on the process, they described that the toolkit provided a "different lens on the activities that we are doing". The checklist helped them to consider the diverse needs of participants: "One thing I remember taking note of was ... some of the workshops use digital tools... Some students with special educational needs might find new digital tools a bit overwhelming, and that is something which we didn't consider". In such a way, the Design Principles and Methods Toolkit have already contributed to approaches to learning experiences outside of SySTEM 2020 in an innovative open schooling project that hopes to share practical approaches internationally.

Further to this, the Design Principles were used by the same team in order to draft and refine the Diversity, Equity and Inclusion Policy Deliverable[25] for the entire OS Hub project. As described by the researcher who developed the deliverable, the Toolkit was "hugely informed by what people said in the design principles", enabling the work of the SySTEM 2020 consortium to impact an entire approach to DEI in another European project.

Title: Zines and Evaluation Methodologies

SySTEM 2020's focus on evaluation and evaluation processes in particular have been embedded into Science Gallery's processes, which have in turn gone on to effect change in further organisations and areas of the informal science learning field. The Head of Communications at Science Gallery Dublin specified that "evaluation is definitely to be kept at the core of everything that we do", demonstrating the importance of SySTEM 2020's reflective and iterative approach. In particular, evaluation processes from SySTEM 2020 were used directly for Science Gallery Dublin's first online Artist in Residency initiative, as part of a collaboration with Human Insights Lab at Accenture The Dock, Dublin, Ireland.

The zine method is a specific evaluation tool developed within the SySTEM 2020 project which is not only unusual; "it's very different approaches to learning across the rest of the college, which is really nice. That's really good and really valuable. Something like even the reflections from SySTEM 2020, using the zines to do that, I think, is not being done anywhere else", but also well received and enjoyable for participants. Reflective evaluation in the form of zines has been shown to make SGD stand out, and this tool in

[25] https://oshub.network/download/D_4.1.pdf

particular was used by the Events team to run an event for Irish National Drawing Day in collaboration with the National Gallery. The first of our online workshops, which went on to pave the way to many online workshops entitled "Messin' Sessions" over Summer 2020. Zines have since been used within further Science Gallery Dublin, Ecsite, Tech Scéal and OS Hub events and programmes, as well as being the focus of a current academic paper (Brown et al., In Review). Further to this, the reflective zine methodology will be shared further among the Science Gallery International Network through an Open Session training event in June 2021, further disseminating the method internationally as far as the US, Australia and Europe.

Title: SySTEM 2020 Map

The final example of a SySTEM 2020 tool impacting the wider learning landscape is the SySTEM 2020 Map and its use throughout Ireland. Having reached out to Science Gallery Dublin to list the organisation on the Culture Near You map, the Dublin City Council were referred to the SySTEM 2020 map, which they then used to look up, contact, and map science and transdisciplinary institutions listed on the map within Dublin's offerings of culture, to be used by many living in and visiting the city. In addition to this, a project taking place in West Ireland at University College Cork who planned to map maker labs in West Ireland contacted SySTEM 2020 to follow up with contacts on our map. Following this, the Research & Learning Coordinator at Science Gallery Dublin now sits on the Advisory Board of this research practice project in the West of the Country.

4.5 Impacts at a social, political, technological and economic level

Finally, selected impacts from the case studies above are briefly situated along the four axes of social, political, technological and economic, helping to illustrate the wide-reaching outcomes of the project.

Social Impacts from the project are both direct - e.g. increased interest and engagement in science and science related learning activities on behalf of learners, and indirect - e.g. supporting organisations to better engage with audiences through tools such as the Design Principles, the learning portfolio tool, and peer organisational support through the map. The adoption of these methods by organisations is not bound by the project timeline but will continue well beyond the project lifeline due to the value of the tools and approaches. Some key examples of this include the use of zines in Science Gallery Dublin and LATRA and the use of Design Principles to organise programmes at

Kersnikova. Therefore the ramifying social impacts and advantages to learners will outlive the project timeline thanks to the long-term adoption of these tools.

Politically, the project has equipped partners and third parties with the information (e.g. project research findings) and the platform (SySTEM 2020 map, website and social accounts) to host webinars with practitioners, researchers and influential individuals and to host meetings with policy makers and civil servants in their countries. The visibility of the project has resulted in certain organisations being invited to play a role in national science learning initiatives (such as Tom Tits in Sweden and Muzeiko in Bulgaria), connections which have been seeded by and supported through the project, but which will continue to affect the non-formal learning landscape in the future.

An obvious technological impact lies in the SySTEM 2020 map, the first of its kind to link science learning organisations across Europe, which provides an opportunity for connection and collaboration within and beyond national boundaries. In addition, the creation of the map in itself was a technological achievement and learning experience for the website developers with whom Ecsite worked. The map will continue to be hosted online as a resource and an open access data set for the next three years. Project partners will continue to share and promote the map as a useful technological tool for collaboration in non-formal science learning beyond the project.

Economically, the project will have long lasting impacts on the institutions within the consortium, who have benefitted from the resources within the project, and the tools and research produced by the project to improve their practice. Building capacity in the participating institutions will contribute to developing effective, meaningful and efficient practices that will result in institutions that are more economically viable in the long term. The example of Tom Tits in Sweden shows that involvement in this project has also led directly to further institutional funding. This, alongside the recent submission of a collaborative project proposal by LATRA and Science Gallery Dublin, who hope to receive funding to continue their work together in the future, demonstrates that long term economic support fosters further project impact through extending the timeline in which the project's approaches are used and shared more widely.

5 Discussion

As the Final Evaluation and Impact Assessment Report for the SySTEM 2020 project, this document has attempted to:

- Summarise the multi-level findings of SySTEM 2020
  - on learners
  - on institutions and practices
- Understand and document the impacts of the research findings and their associated activities
  - on learners
  - on SySTEM 2020
  - on organisations beyond SySTEM 2020
  - on the wider science learning community

The rich learnings, tools, and approaches shared in Sections 2 and 3, supported by academic publications, conference papers and webinars, help to demonstrate the insight that the SySTEM 2020 project has produced in terms of understanding the field of informal and non-formal science learning from multiple perspectives. Section 4 goes on to demonstrate the ways in which these tools, approaches and understandings have had lasting impacts on those involved in the project, and those who are less involved but have benefited from or been able to put the work to use in their own context. The following reflections help to summarise this report.

The SySTEM 2020 map, the first of its kind, provides a wealth of information about existing practices in informal science learning across Europe. It is clear that this open access dataset can continue to be used by researchers, practitioners and audiences alike as a tool to make science learning more visible, and as a result, accessible for both those who work in and engage with this field. Though, it must be noted that map data is self-reported by the organisers of learning activities and does not provide any measure of the quality of the activities or the impacts of the learning outcomes. As such, it should be seen as one view of non-formal science learning across Europe, rather than the only view. Yet, despite this limitation, the map has created multiple instances of collaboration between organisations, practice sharing, and increased visibility for audiences. On top of this, the SySTEM 2020 map and resulting network is a perfect visual description of the breadth and depth of this project.

Throughout SySTEM 2020, the value of qualitative reflections and deep rich understanding has been balanced alongside the strength of quantitatively mapped data. This mixed methods approach has enabled findings on a variety of levels, from cohort analysis of science attitude trends to experiences of practitioners and learners with novel research and evaluation tools. Drawing together which explores widespread trends (the map, the longitudinal survey), with smaller samples of richer and more in-depth data (the self-reflection tool, the ESM, the learning portfolios), has aided the construction of an understanding of learners' experiences of science learning, and institutional perspectives on enabling and furthering such learning processes. The use of in-depth case studies, which tell a detailed story of a specific instance of science learning or development, demonstrate just how much rich detail is inherent in instances which exist within broad scale quantitative data.

The mixed-method approaches have enabled the exploration and recognition of the importance of well-designed and delivered learning experiences in a learners' development of their science identity. In particular, SySTEM 2020 found that learning pathways run within and between learning environments, a finding which arose through the learning portfolios, longitudinal survey and self-evaluation tool. The tools in Work Packages 4 and 5 were designed to support organisations to deliver positive learning experiences to a diversity of learners, and in doing so will effect change on an institutional level as well as an individual level for learners who experience the resulting learning programmes. Such work contributes to the reinforcement of positive learning loops through inclusive and equitable non-formal practice. As is clear from this report, and many of the outputs from Work Package 3 and 6, this project also has developed research and evaluation tools which enable an understanding of learners' experiences in relation to the activities they have taken part in. In such a way, SySTEM 2020 offers tools to adapt and design learning programmes, as well as tools to reflect on and alter these according to learners needs. Such an approach encourages science learning institutions to tailor their activity and iterate approaches to best support their own learners' experiences.

The impact assessment within this report already demonstrates the usefulness of the project tools and activities at multiple levels in the learning landscape. Yet the findings reported so far are an indication of the longer lasting impact that is yet to come. So far, the tools and methods of the SySTEM 2020 project have already begun to transform organisations and individuals alike. Yet, this impact will in turn lead to further impact in the future; whereby altered or new learning programmes that emerge as a result of the project will go on to effect change in learners and staff and collaborators in the years to come. While these longer lasting impacts cannot be reported on during the timeline of the project, the strong indication of change wrought by the project so far is the best possible indicator that more positive changes are to come.

However, it is important to remember the time-bound nature of this project. Though tools and practices are expected to live on in years to come, it is clear that much of the support system that is linked to these will reduce as time since the project passes. Further research-practice partnerships spanning formal and informal learning, particularly those that are supported over longer timescales will be crucial to explore longitudinal effects, and to fully realise the potential of true design-based implementation research, wherein research and practice can be mutually beneficial, reflexive, and can productively iterate over time. Useful work in this space that such projects might address could be the further extension of learner-centred tools which support the assessment of soft skills, self-assessment and creative self-evaluation. Yet the need for more robust data must be carefully balanced against the naturally informal nature of these learning environments, in order to ensure that this delicate learning ecosystem is not knocked out of balance.

Science learning outside of the classroom is a nebulously broad field, and one that SySTEM 2020 has attempted to contribute to with wide-ranging, but not all-encompassing approaches. The project partners span Europe and Israel and serve distinct learners, which provides a breadth to the project which is useful in suggesting some conclusions related to the approaches to, experiences of and barriers that prevent science learning. Yet, it is important to recognise that these results are contextual, and in the legacy of the project it is hoped that critique and engagement from further practitioners and researchers in the field will result in further exploration and understanding of the complexities of science learning.

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7 Appendix

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