Reshaping Science Learning Outside the Classroom

Findings and Recommendations from SySTEM 2020

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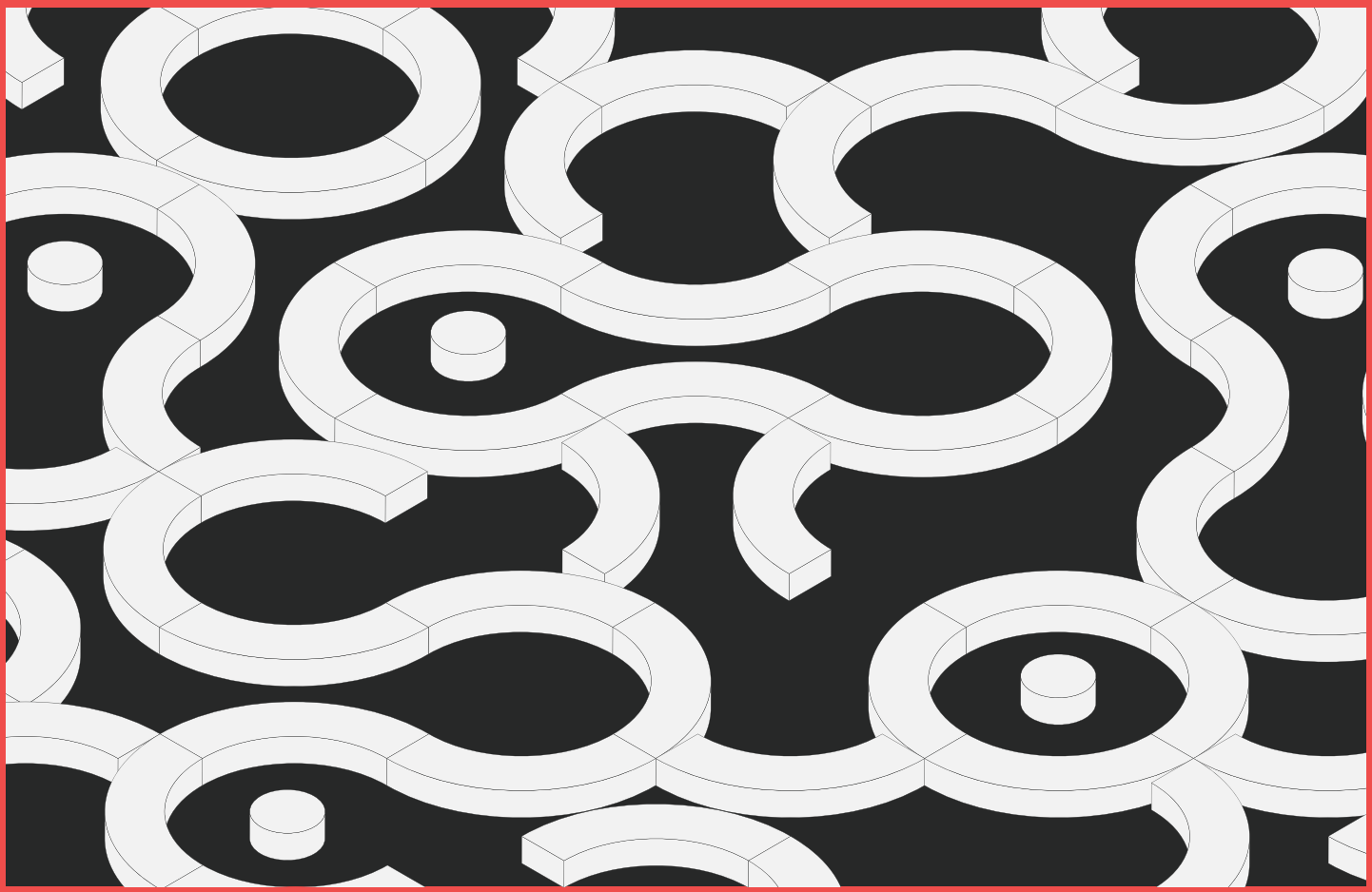

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Permanent link to all tools and resources is on the SySTEM 2020 Zenodo community

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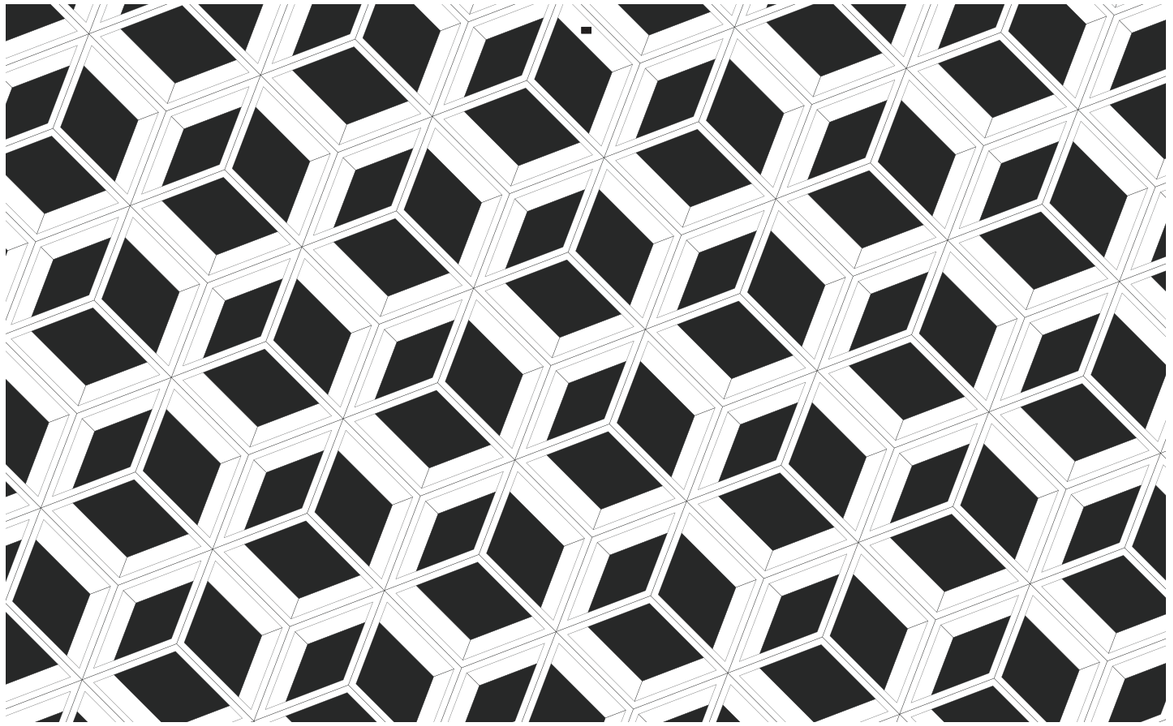
Foreword



Belgrade, February 2020. The SySTEM 2020 partners flew in from all corners of Europe, from Finland, from Greece, from Ireland, and from everywhere in between. We were excited to be together, nearing the final year of the project - at that point we didn't know this would be our last face-to-face meeting, and for most of us, the last chance for international travel for at least a year. Thinking back, this moment when we could share a coffee while taking a break from intense working sessions, or walking through the city centre and chatting about the Christmas lights still being up in mid-February, is even more cherished, and will be one that lives on in our memories. One year later, one year into the pandemic, we are still united by SySTEM 2020. In this intervening year, more learning has happened outside of classrooms than ever before, and we as a consortium of 22 organisations are still united in trying to re-imagine science learning outside the classroom in this new and uncertain world.

Over the past three years, we have been lucky to be working in an atmosphere of support, trust, and shared values. This has been a remarkable collaboration of researchers and practitioners on a mission to map the field of non-formal science learning, and to support and empower young learners. All of our findings and research results are rooted in the practices of non-formal science learning organisations. They have been tested, iterated, discussed and are now on offer to the wider community.

We have been researching theory and practice in science education outside the classroom. Through this work, several trends and divides have come to the fore that require institutional and policy responses in order to turn the tide, and begin moving towards a systemic change in science education.

We have created a series of adaptable and practical tools for educators that will support and cultivate learners' interest in science. These tools have been curated to respond to the growing need to ensure that we create pathways to welcome learners from all backgrounds into science learning, and meet them wherever they are. We

hope that our work will support the integration of learning ecosystems which link formal and non-formal education, families and wider communities, spanning a range of subject disciplines and supporting multiple ways of knowing and learning.

The possibilities for all should be, and can be, within our reach. Our research and tools can frame priorities, agendas and policies that position Europe at the forefront of developing an equitable and diverse science learning landscape. This is why we are honoured and excited that two high-level politicians are endorsing our project and this report. We hope you enjoy the read and most importantly that this report will act as a catalyst for change.

Dr Mairéad Hurley
SySTEM 2020 Principal Investigator,
Trinity College Dublin

As Minister for Health during the emergence of COVID-19, and now as Minister for Further and Higher Education, Research, Innovation and Science, I am reminded every day that difficult problems facing our society can be best tackled by diverse groups of creative thinkers working together. Our education systems need to nurture such agile thinkers and ensure that there are pathways for everyone to achieve their full potential. My Department has a huge responsibility to deliver for the future of Ireland, across a wide range of areas. Key to our country's success is preparation of young people to approach problems with a variety of perspectives, to learn through mistakes and resilience, and to play an active role in realising a better society for all.

With this report, the organisations in the SySTEM 2020 project, spread across 19 countries, demonstrate the great value of learning experiences which happen outside of formal education. Through their activities, they promote creativity and collaboration by allowing young people to explore their interests through various combinations of science, technology, engineering and mathematics, and the arts. These experiences go hand-in-hand with classroom lessons in preparing our young people to thrive in our new reality.

It is becoming increasingly evident that public engagement with science, technology, engineering and mathematics is crucial as we tackle global-scale issues such as climate change, data security, and of course, public health crises. SySTEM 2020 was envisioned and led by Science Gallery at Trinity College Dublin - founding member of an international network of eleven leading universities worldwide. The Science Gallery network, and the member organisations of the SySTEM 2020 project are exemplars, engaging citizens with these topics and promoting active scientific literacy. These organisations connect with millions of learners annually, reminding us that education and learning does not stop at the school gates. To support the critical thinkers and active voices of the next generation, it is crucial that we build sustainable

transdisciplinary networks of stakeholders spanning education, science, innovation, research and policy, and of course, young people themselves. I am confident that this report will be a valuable asset to those of us who share this vision of the future of learning.

Simon Harris T.D.
Minister for Further and Higher Education, Research, Innovation and Science, Ireland

I am very pleased to endorse this report on the Science with and for Society (SwafS) Science Education funded project SySTEM 2020.

The European Commission has invested heavily in science education over the past 10 to 15 years, acknowledging the importance of science education as part of a learning continuum for all. SySTEM 2020 is a fantastic, successful example of this investment!

SySTEM 2020, with its 22 organisations, focuses on science education outside the classroom and offers a wonderful series of current, adaptable tools for educators to support and cultivate learners' interest in science. It has a special focus on equity, inclusion and gender. STEM educators require a particular attention to learners from minority, economically disadvantaged and migrant communities. This is where SySTEM 2020's strategy to provide practical approaches to ensure equity, inclusion and gender balance in STEM fields of study will pay off.

Science education should balance requirements of breadth and depth of knowledge to ensure young people and adult learners are motivated to learn and are equipped to engage in scientific discourse. The project addresses these needs.

The European Commission's Horizon Europe Work Programme, to be published this year, will continue to expand opportunities for science learning in formal, non-formal and informal settings.

Research and innovation are essential to finding solutions to the pressing challenges we face. Europe cannot thrive without ensuring the best possible match between the immense potential achievements science has to offer and the needs, values and aspirations of our citizens. Science education has an important role to play.

I firmly believe that investing in science education is investing in Europe's future.

Mariya Gabriel
EU Commissioner for Innovation, Research, Culture, Education and Youth

SySTEM 2020 Project Partners

Partner Name	Country
Science Gallery at Trinity College Dublin	Ireland
Ecsite	Belgium
Aalto University	Finland
Zentrum Für Soziale Innovation	Austria
Waag	Netherlands
Ars Electronica	Austria
Kersnikova Institute	Slovenia
Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci	Italy
LATRA	Greece
Centre for the Promotion of Science	Serbia
Bloomfield Science Museum	Israel
European Molecular Biology Laboratory	Germany
Raumschiff	Switzerland
Fundação da Juventude	Portugal
Muzeiko Foundation	Bulgaria
TRACES	France
Science Gallery at King's College London	United Kingdom
uTesla	Czech Republic
Technopolis	Belgium
NOESIS	Greece
Tom Tits Experiment	Sweden
Parque de las Ciencias	Spain

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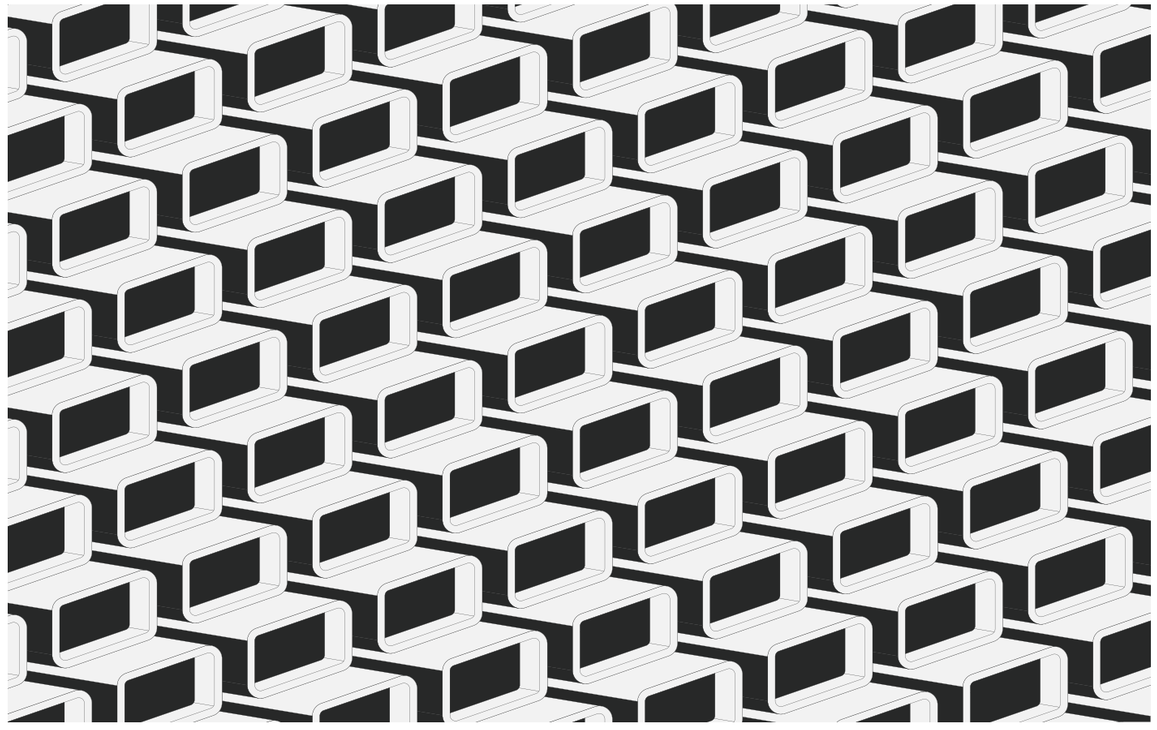
Photo credit: Parque de la Ciencias

The State of Play: Science Learning Outside the Classroom



Firstly, what is the difference between formal, non-formal and informal learning? The SySTEM 2020 project settled on the following definitions[1], chosen for their universality and inclusiveness:

Formal	Non-Formal	Informal
Learning that takes place through a structured program of instruction which is generally recognised by the attainment of a formal qualification or award for example, a certificate, diploma or degree.	Any organised and sustained educational activity that does not correspond exactly to the definition of formal education. Non-formal education may therefore take place both within and outside educational institutions, and cater to persons of all ages.	Learning resulting from daily activities related to work, family or leisure. It is not organised or structured in terms of objectives, time or learning support. Informal learning in most cases is unintentional from the learner's perspective. It typically does not lead to certification.

The primary attributes of formal, non-formal and informal learning are: institutional learning objectives; learner intention; learning approach; and finally, assessment and/or qualification. SySTEM 2020 recognises that a learning experience may be understood along a spectrum of educational modes between the three categories (formal, non-formal, informal), depending on the distribution of these four attributes. Our project also refers primarily to science learning outside the classroom within its title, but we recognise that in many of the SySTEM 2020 settings, science is integrated with other subjects, most commonly technology, engineering, or mathematics, which together comprise the acronym STEM. Additionally, many SySTEM 2020 partners combine STEM learning with the arts, and this transdisciplinary approach is often labelled STEAM. We use these terms fluidly within this report depending on the particular focus of the partners or the activities in question, but in the general case we will use the term science, as it is science which is common to all learning activities covered in the SySTEM 2020 research.

1. As presented by the National Centre for Vocational Education Research of Australia

Where is non-formal science learning happening?
Good question! We thought it would be useful to know the extent of non-formal science learning opportunities, and so we created an interactive map to show us just that. As of May 2021, there are 1456 organisations offering non-formal learning activities in 25 countries shown on this map. Map entries contain a wealth of information about an organisation - the activities offered, the cost to participate or to enter, the age range catered for, the specific topics covered, the pedagogical approach, 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 or pure interest. 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 visualisation options available.

Explore the SySTEM 2020 map

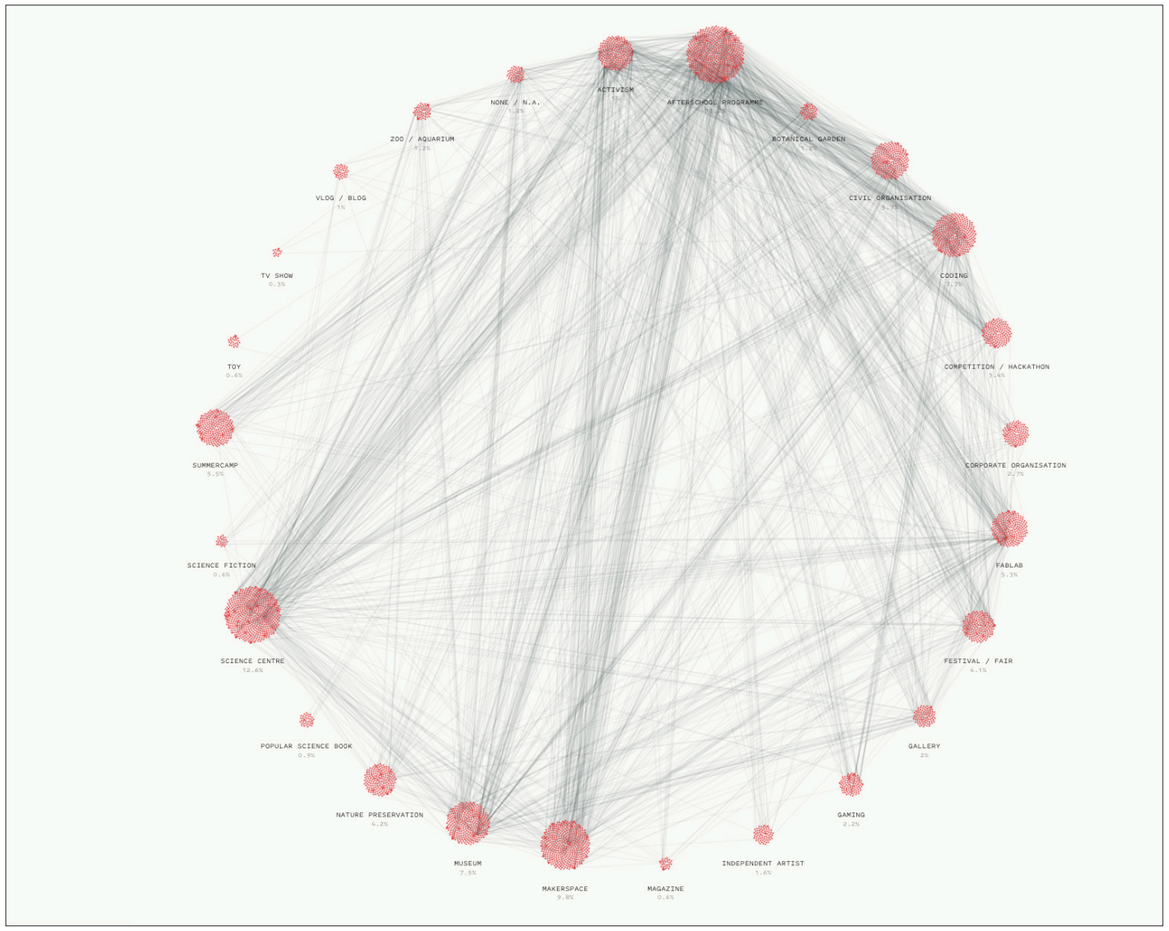
"Through working on the map, we gained a much clearer view of the STEAM landscape in Switzerland and, to some extent, in Europe and the different ways in which STEAM learning outside school takes place."

Hanna Sathiapal
Co-founder, Raumschiff, Switzerland

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

Anelia Fernandes
Project Manager, Muzeiko, Bulgaria

SySTEM 2020 map displaying institutions as nodes and connections between them indicating collaboration and practice sharing.



Visualisation of SySTEM 2020 map organisations by type. Lines demonstrate the interactions and collaborations between different forms of science learning institutions.

How do young people experience science learning?

The way young learners experience science learning and how they connect with science depends on multiple interacting factors. We have explored the science learning experiences of almost 3000 young people aged between 8 and 21 years in 17 European countries and in Israel, including those from geographically remote, socio-economically disadvantaged and migrant communities. The science engagement organisations involved in the project each serve distinct audiences, and each partner uses unique methods to tailor their activities to the needs of the more accessible to groups and communities who are under-represented in science in their locality.

Learning is a socially embedded, cognitive, emotional and behavioural process. It 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[2]. 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, we combined a number of approaches. Traditional survey methods provided a global assessment of the science attitudes and science engagement of young learners. Time-sensitive survey methods were used to provide information on the variability of the learning process. To measure the change in learners' specific skills, a self-assessment tool was employed. Different qualitative approaches including zines, self-reflection and an "observation mapper" allowed young learners to document and reflect on their learning experiences and observations made during STEAM workshops.

More than 80% of all surveyed young learners (n=882) pointed out that they are interested in specific science-related topics - the human body and genetics, animals, computers and planets were named most frequently. Interest in science, however, only forms one part of the broader factor of so-called 'science attitudes' which also captures the way learners relate science to their everyday lives. One of the factors that best explains the development of a positive attitude towards science is the enjoyment of science lessons in school. Learners who enjoy science lessons in schools are also more likely to like science in general. Learners who perceive their performance at school better are also more likely to exhibit a positive science attitude, re-emphasising the link between the formal education system and general attitudes towards science.

The self-motivation of a learner to engage in all kinds of activities which potentially foster informal science learning was also found to be an important factor contributing to a positive science attitude. The higher the self-motivation, the higher the likelihood of showing a positive science attitude.

The development of a positive science attitude is further influenced if science is relevant in the learner's home, and is also more likely when their peers also enjoy science learning. Both influencing factors, in turn, are shaped by age, with the social environment being particularly important for younger learners.

We see a strong influence of the educational background of parents on young learners and the probability of their developing a positive science attitude, or to consider the possibility of further study or a career in STEM. The more highly educated the parents of young learners, the higher the probability they enjoy science learning and consider it useful or relevant to them. Privileges overlap and reinforce one another in relation to science leaning, with boys from highly educated backgrounds being the most likely in our sample to identify with science.

Three distinct dimensions of science learning activities for young learners emerged from our survey sample (n=882):

- Self-directed science learning covers activities such as science experiments at home, as well as watching videos about science related topics and creating or building things. Just under one quarter (23%) of the surveyed learners regularly engage in this form of

2. STEM Learning Ecologies: Relevant, Responsive and Connected. Bronwyn Bevan (2016). https://www.nsta.org/connected-science-learning/connected-science-learning-march-2016/stem-learning-ecologies

science learning in an out-of-school context.

- Arts-centred learning covers the regular engagement in activities such as playing musical instruments, singing, dancing or participating in drama classes. About 25% of the surveyed young learners pursued arts-centred activities (which can foster informal science learning) at least one a week.
- Sports-based activities refer to potential events of informal science learning when engaging in team sports and training in sports clubs. The number of young learners pursuing sports activities was highest among young learners, with about 44% of the youngest age group (8 to 11 years) regularly engaging in these kinds of activities.

Within our sample, male learners were more likely to engage in self-directed science learning activities as well as in team sports. Female learners, in turn, tended to engage more often in arts-based activities. Whereas this difference was not significant when comparing learners from low educational backgrounds, gender-based differences were exacerbated with higher educational capital, and were most pronounced among learners from highly educated households.

The enjoyment of science lessons in school was not affected by any group differences with regard to gender or family educational level, but attitudes towards science in general were: male learners from highly educated households tended to see most strongly how science relates to their lives and showed the most positive science attitudes.

In addition to the survey carried out as part of SySTEM 2020, analysis of further in-depth qualitative research with a smaller group of young learners demonstrates that non-formal STEAM workshops do impact learners' own understanding of their skills and achievements. Learners reported the following outcomes:

- Increased confidence or self-worth
- Increased self-belief in their mastery of "21st century skills" - collaboration, critical thinking, creativity and

communication

- Seeing how science and art relate to one other
- Resilience - understanding mistakes and keeping on trying
- Feeling able to interact with, or use, STEAM subjects or content knowledge

Photo credit: Ars Electronica

Spotlight on Inequalities

"Equity is not abstract concept. It is something that is actively constructed every day. It is tiny things from how employees at the info desk talk and how the security staff interact to what is happening in your cafe. If you don't involve all areas in the institution, you can have an inclusive activity, but your institution might be discriminating. You really need to make a commitment."

Dr Eva Durall
Postdoctoral researcher, Aalto University, Finland

In science education, work towards equity requires a holistic understanding to consider how organisational processes and external factors affect access, diversity and inclusion. SySTEM 2020 identified eight approaches that policy-makers and decision-makers can adopt to improve equity within informal science education. These eight equity approaches, identified in the **SySTEM 2020 White Paper on Equity**, seek to raise awareness of the importance of considering equity as a lens through which to look at the organisation as a whole. The White Paper was developed through a series of co-design sessions with 19 invited experts in informal/non-formal science education from 14 countries, as well as a further session with expert members of the SySTEM 2020 consortium and our External Expert Advisory Board. The key equity action approaches and some suggested strategies to implement them are outlined in the following table.

Action approach	Strategy
Framing	• Incorporate equity into the organisation's values, vision and mission state-ments, 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 educa-tion. • Think big and work towards a desirable future

SySTEM 2020 White Paper on Equity

In summary, the key messages are:

1. To have impact, work towards equity should also consider the organisation's mission, values and organisational processes.
2. Equity is 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 organisations' activity.

As SySTEM 2020 ends, now is the time to start doing the real work in our own institutions and countries. Research is often hard to put into practice and one of the best things about SySTEM 2020 is that it is so practice-based. As a field, we already know that not enough girls go into STEM careers. We know that people from disadvantaged groups struggle to get involved with science. But what do we do with this knowledge and how do we improve our practices? SySTEM 2020 is providing some of the answers and tools we need.

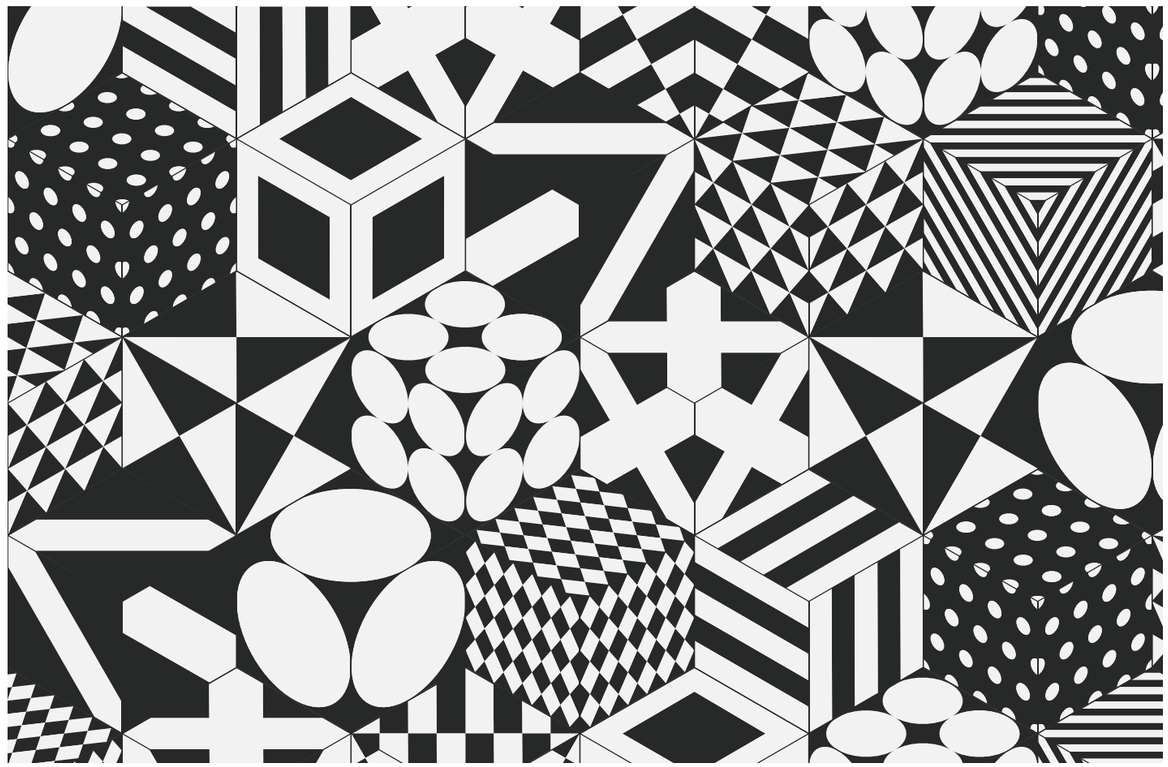
With SySTEM 2020, we have started this journey in our own organisation. Our aim is to have the entire organisation make informed decisions based on the main principles of informal learning, science capital and equity: from the exhibitions department, to what we sell in our shop, to how we present our cafe. For example, now we are training our marketing department on how to write in an inclusive way and how to extend learning through social media using cultural references that speak to the visitor.

In Sweden, formal learning is funded by local governments. If you want to play football, you have an association. For music, there is a music school with trained professionals. But in informal learning, it is not centralised or structured. My hope for the future is that all people working in informal learning in Sweden can access best practices supported by research on equity. SySTEM 2020 provides the essential groundwork to make this hope a reality.

Cecilia Ekstrand
Senior staff of Education & Public Engagement,
Tom Tits Experiment, Sweden

Photo credit: Ars Electronica

Designing Science Learning Experiences for All



Designing for equity in informal science education is one of the equity action approaches. It means cultivating inspiring learning environments where learners' cultural resources are recognised as valuable. Equity-focused informal science education demands that everyone involved has critical agency, especially educators and learners.

The **SySTEM 2020 Design Principles and Methods Toolkit** is a project output which supports the development of equitable non-formal science learning activities and environments. It contains a set of methods for designing science learning activities that take place in spaces such as science centres, makerspaces, museums, galleries, and gardens. The toolkit is aimed at non-formal science educators or programme managers. It supports the design and facilitation of meaningful science learning activities and programmes, with an emphasis on nurturing inclusive science learning. It is built around three main principles:

Design for everyone
People are diverse and everyone should have opportunities to participate in science learning regardless of their personal or social circumstances. Supporting equitable approaches to science learning outside the classroom demands a special effort to ensure that the content and the context of science learning is accessible, diverse and inclusive.

Design for experience
Great learning experiences are meaningful, engaging, inspiring and trigger further learning. In education, design for experience is dependent on the environment where the activity takes place. Many contexts in which informal science learning happens are social spaces. Facilitating successful learning experiences in these contexts requires paying attention to what inspires and motivates your participants.

Design for growth
Lifelong learning is as important for learners as for practitioners. In science education outside the classroom, the learners and educators' sustained growth should be cultivated. In the case of learners, this means helping them become autonomous, as well as building pathways for learning and supporting their science identities. For educators, the emphasis is on developing self-evaluation skills that will help them improve their practice.

Explore the SySTEM 2020 Design Principles Toolkit

Explore the SySTEM 2020 Co-Design Materials

"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."

Halinka De Visscher
Project and Planning Manager, Technopolis, Belgium

The SySTEM 2020 Design Principles Toolkit was developed through a series of participatory co-design workshops involving multiple project stakeholders. Co-design is an approach to design that advocates for the active involvement of people without professional design training in the creative process. Co-design is based on the assumption that people are creative and are experts on their own lives. From this point of view, designers need to engage diverse stakeholders in the design process to create solutions that respond to people's needs and are usable. SySTEM 2020 has produced a set of co-design materials that can be adapted and implemented by educators in a range of settings.

Sometimes facilitators are not thinking about all the aspects and processes that come with designing an educational workshop. The SySTEM 2020 Design Principles Toolkit is not only about the gadget, the topic or product, it's also about relationships, understanding participants' feelings, being able to understand that your audience is not diverse enough. It makes it clear to facilitators why things need to change as well as confirming the good practices that they have already been implementing intuitively. The toolkit is extremely well structured, based on research and co-designed by organisations from nineteen countries. We made it collectively with stakeholders and, most importantly, learners.

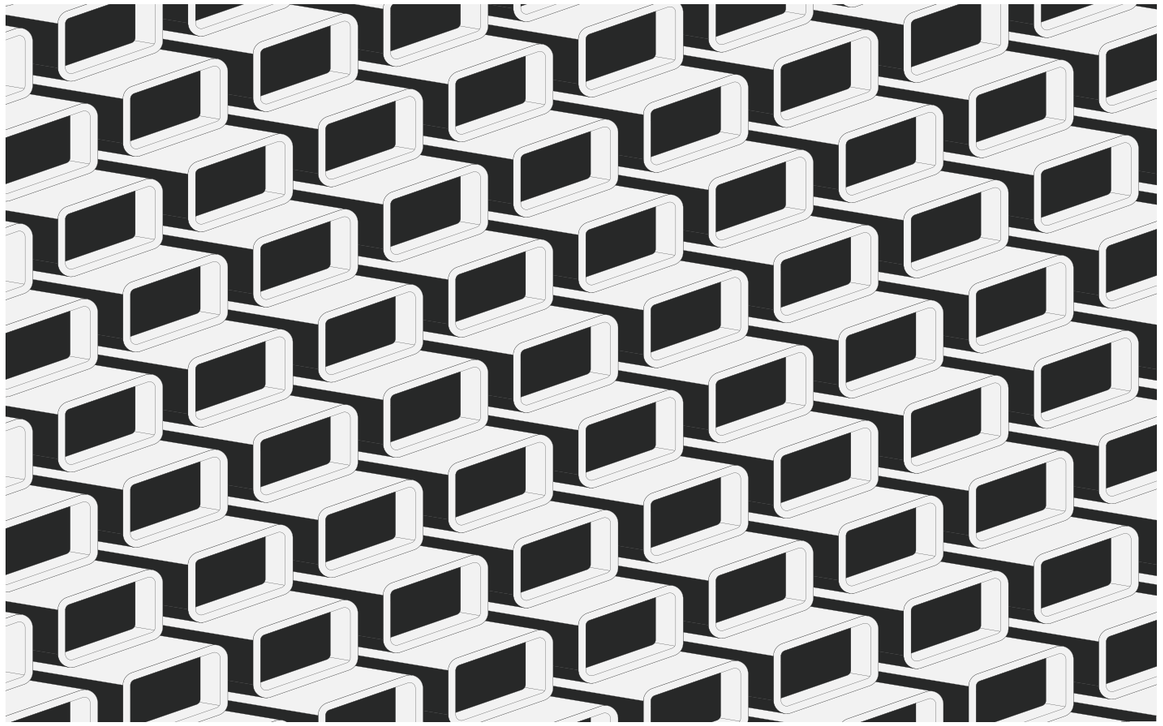
Now the project toolkit is completely embedded in our institution. We made a whole workshop out of it and we will be using it to train all new facilitators. For us this is a very practical tool - that is the best possible outcome of a European project. Together we created new knowledge and now we adopted it at Kersnikova. That's how you grow.

Urška Spitzer
Producer, Kersnikova Institute, Slovenia

Photo credit: Science Gallery Dublin

Photo credit: Waag

Exploring Evaluation



As an institution, Ars Electronica is not used to using evaluation and assessment to design and implement processes. We are strong on implementing programmes and engaging learners, but usually the process stops there. For us, SySTEM 2020 got the “thinking and doing” process started. It was a huge takeaway to see what different types of evaluation are out there and what can be used for different types of activities. We saw that these methods could be used to engage audiences in the long run, to try and build relationships, especially for kids and youngsters. The success story in our case is that we understood that evaluation goes hand in hand with implementation and can serve us throughout our cycle of activities.

Veronika Liebl
Director of European Cooperation, Ars Electronica, Linz, Austria

SySTEM 2020 developed a set of tools aimed at evaluating the delivery and impact of science learning that occurs outside the classroom.
These research instruments may be useful to non-formal science learning organisations and practitioners, and the SySTEM 2020 Toolkit of Frameworks, Tools and Practices will help with adapting and deploying them in a variety of contexts. An important aspect that emerged in discussions among consortium members when considering the development of evaluation approaches was to try to move towards tools that could inform the educators as to how learners were engaging with the content, but that could also be a creative and personalised process for the learner.

SySTEM 2020 Toolkit of Frameworks, Tools and Practices

Holding up a mirror to equity in learning: self-assessment
Skills like creativity, communication, collaboration, and critical thinking can be difficult to define, as they are quite subjective. How can one assess whether learners possess, apply or hone these transversal skills while learning science outside of the classroom? A standardised test is not available, as it might be next to impossible to construct one for such subjective experiences, and may be undesirable, as it could be seen as excluding learners and promoting a punitive notion about skills. It might also jeopardise the very nature of certain organisations or activities which are often successful in engaging otherwise disengaged youth, precisely because they are unlike what they encounter in school. SySTEM 2020 took a different approach in developing tools for self-assessment of transversal skills. Self-assessment of skills is formative assessment: not a standardised test, but rather a structured set of open-ended questions that can be answered in a questionnaire or interview. Firstly, self-assessment helps learners to better identify the skills they are activating during an activity, and to express their experiences as they do so. This meta-cognitive approach would ideally support the learner to be able to think about this skill on a future iteration of the activity, and to challenge themselves to improve or to hone it more effectively. Secondly, the practitioners can get

institutional information from these expressed experiences, such as how to improve their activities as learning experiences or in a certain social context, how skills are related to their activities by learners, or by simply finding out what their activities mean to their learners.

In SySTEM 2020 two self-assessment tools were developed: a Self-Reflection Tool, and a Self-Evaluation Tool. The Self-Reflection Tool focuses more on the experience than on skills, and is a lightweight, flexible, but effective self-assessment tool. It is recommended for short activities (e.g. museum visits) or online activities, also when learners and facilitators change regularly. As it is shorter and simpler, it is also recommended for younger learners.

The Self-Evaluation Tool requires more time and effort to implement, but gives a more complete set of results. We recommend using it alongside longer and more structured programmes, e.g. multi-day camps or workshops, term-long or year-long after-school programmes. The learners using this tool will benefit from continuous facilitator support to monitor self-evaluation during the programme. In an ideal case, educators working with researchers within a "research-practice partnership" can collaboratively use the results to improve the programme, and to provide targeted support to the young learners involved in the self-evaluation process.

The SySTEM 2020 Toolkit of Frameworks, Tools and Practices provides details instructions, case studies and sample questions in multiple languages for those wishing to test or adapt these tools.

Photo credit: EU Researcher's Night at Science Gallery Dublin

At Science Gallery Dublin, we used the SySTEM 2020 Self-Reflection Tool during one of our programmes that was moved online because of the pandemic. Reflection and evaluation were instrumental in working towards an optimised online learning experience for youth participants. Without physical cues and natural conversation to determine how learners were experiencing thewith activities, the tool helped us to gauge the participants' engagement and to adapt the programme in response.

The tool gave learners the chance to assess the skills obtained during their experience and to reflect more generally on the activities. One of the questions learners were asked was: How do you think this topic may impact you and/or others? Here are some of the responses:

- "I think it can help you organise your thoughts which is very important in the current climate"
- "It will improve our creativity. I don't know about others, but it has boosted my curiosity."
- "It made me think and reflect."

These quotes help to show how a qualitative and open-ended tool can make space for learners to consider their experiences.

Sophie Perry
Research & Learning Coordinator, Science Gallery Dublin, Ireland

Exploring Evaluation

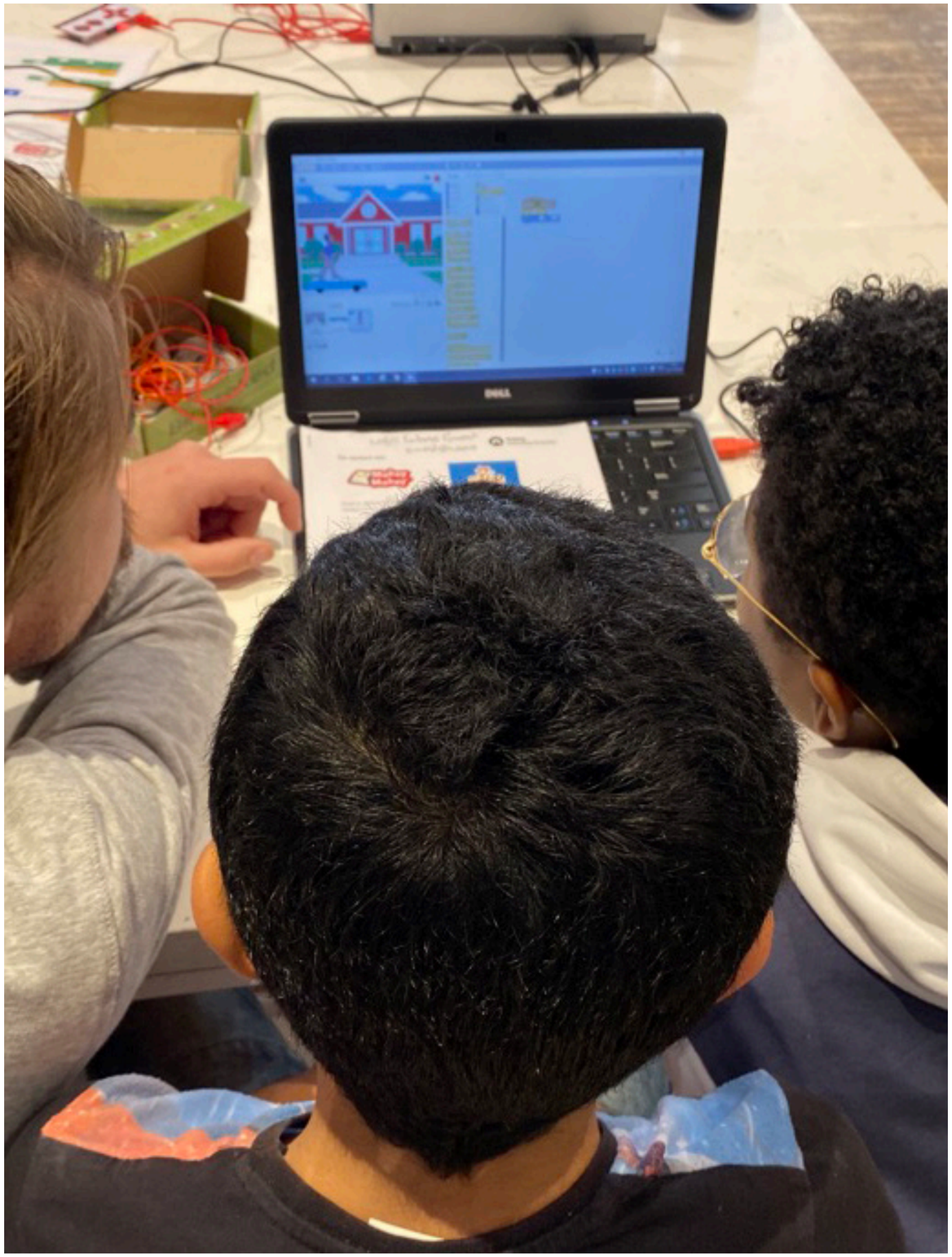


Photo credit: Waag

SySTEM 2020 Experience Sampling - How To Guide

Capturing the moment with the Experience Sampling Method

SySTEM 2020 showed how an Experience Sampling Method (ESM) can be used to assess the influence of STEAM workshops on young learners over time. This method consists of a sequence of questionnaires sent by text message, capturing a young learner's response to prompts about how they feel about science at a specific moment in time.. To trial this method in SySTEM 2020, questionnaires were sent three times to young learners who were registered to participate in an out-of-school STEAM learning activity: in the morning on the day of the event, during the workshop and after the workshop in the evening.

ESM makes use of technology that young people are comfortable with - mobile phones - adding a layer of familiarity and usability. SySTEM 2020 published a How To Guide for researchers as well as workshop facilitators who may wish to adopt a version of this methodology to gain an insight into the evolution of learner attitudes to STEAM learning over time.

SySTEM 2020 Observation Mapper Guide

Navigating data-driven landscapes with the Observation Mapper

Another hands-on tool developed by SySTEM 2020 partner ZSI is the Observation Mapper. The goal is to enable workshop participants to evaluate their own learning under a number of different metrics including their engagement with a topic or time spent on certain activities. The Observation Mapper is a device for exploring ways to make data collection part of reflective sense making, through learning analytics and data visualisation. Primarily, the device is designed to offer informal learners an appealing, hands-on way to track and assess their activities.

The mapper is a hardware device made from simple hobbyist electronics, with basic coding required to set it up to gather different data types. It can be built with learners to provide them with a further dimension to learning aimed at gaining a deeper connection and appreciation of the elements of data science that can be found in a variety of topics. It can introduce them to the creative use of data, increasingly used in digital artworks in the realm of art-science.

For example, in Ljubljana a workshop was designed around the invasive Japanese knotweed plant. Mapped observations were related to the positions of knotweed plants and their respective shapes. Using these visualisations in combination with photos of plants could deepen the learning about where 'invasiveness' is visible and what plants are recognizable at a specific time of the year.

The benefit of such a tool for facilitators or organisations is that it gives them access to data and evidence of the impact a workshop can have. This can be valuable in reflecting on how a workshop went both logistically and in terms of learner engagement with a topic, and in turn support planning for future activities.

Zines: from creative collages to evaluation tools

A further aim of SySTEM 2020 was to examine science learning at the individual level through the production and analysis of learning portfolios. Learning portfolios can take many forms, but typically are documents created gradually by learners over the course of an extended educational experience such as a course or programme. Zines were chosen as a form of learning portfolios which would allow learners to creatively reflect on STEAM learning during SySTEM 2020 workshops. Zines are mini-magazines made through a simple, engaging and fun process. They are often hand-made, non-professional and non-commercial and can contain a mixture of collage, original written text, painting, drawing and more. They serve many functions, from telling stories to giving instructions. They enable a self-led reflective process, guiding learners to engage critically and author their own learning story. It is of particular importance that within their zines, learners are able to relate the workshop content to personal experiences, identities and values, and are challenged to explore fresh connections linking what they have learned with wider societal issues.

Zines proved to be an effective tool for learners to creatively reflect on their learning, whether as part of a personal project, a science camp, workshop or homeschooling activity. They work particularly well with workshops or programmes that are long-term and involve repeated encounters, wherein learners are supported to spend ample time creating their own zine using whatever materials and words they choose, and to return to it as time goes by.

As the pandemic hit, the use of zines took an unexpected twist in SySTEM 2020. Although they were intended as tools for self-reflection for learners, in the context of the confinement conditions, they proved to be especially valuable for participants to document or journal their lockdown experiences and deal with some of the challenges they faced as a result of Covid-19. The decision was taken to dedicate entire online workshops to zine-making, as featured in the programme of Festival Ars Electronica 2020. Additional elements in these online workshops included the history of zine culture, an introduction to different binding methods, and making stories within zines. The workshops were particularly effective online due to the simplicity of the materials required.

SySTEM 2020 Learning Portfolios - Zines

In Dublin, young people aged 15 - 17 were given the power to narrate their learning journeys in Science Gallery Dublin by making zines to reflect on a five-day themed art-science workshop series focused on sustainability. Participants were introduced to topics related to plastic use, waste management, material science, and ecology through interactive, discussion-based workshops. They were challenged to apply their learnings through a collaborative design-based project in which they would ideate, model and present innovative solutions to locally-relevant sustainability challenges. The multi-faceted learning design meant that students were asked to explore, make meaning and critique throughout the various stages of the workshops. The zines in response to this topic varied from instructions for how to make eco-friendly beeswax wraps for food, to opinions about plastic use and dependency. The zines also showcase statements which highlight the personal development for some learners as a result of participating in the programme:

- “improving my patience”
- “it made me feel more comfortable about sharing ideas and expressing myself”
- “have open conversations with everyone”
- “For me, It opened up my mind on being more creative”
- “I learned that it’s good to be imperfect”

Zines offer an inclusive and emancipatory opening to inter- and transdisciplinary thinking and the testing of ideas. It is a DIY medium where creators are able to dissect and reconfigure topics of interest, experiment with new ideas, hypothesise and reimagine futures. As out-of-school learning spaces continue to evolve, tools like zines provide an integral opportunity not only to explore, but to honour the lived experiences, knowledge communities, and values of learners.

Autumn Brown
PhD Researcher, Science Gallery Dublin, Ireland

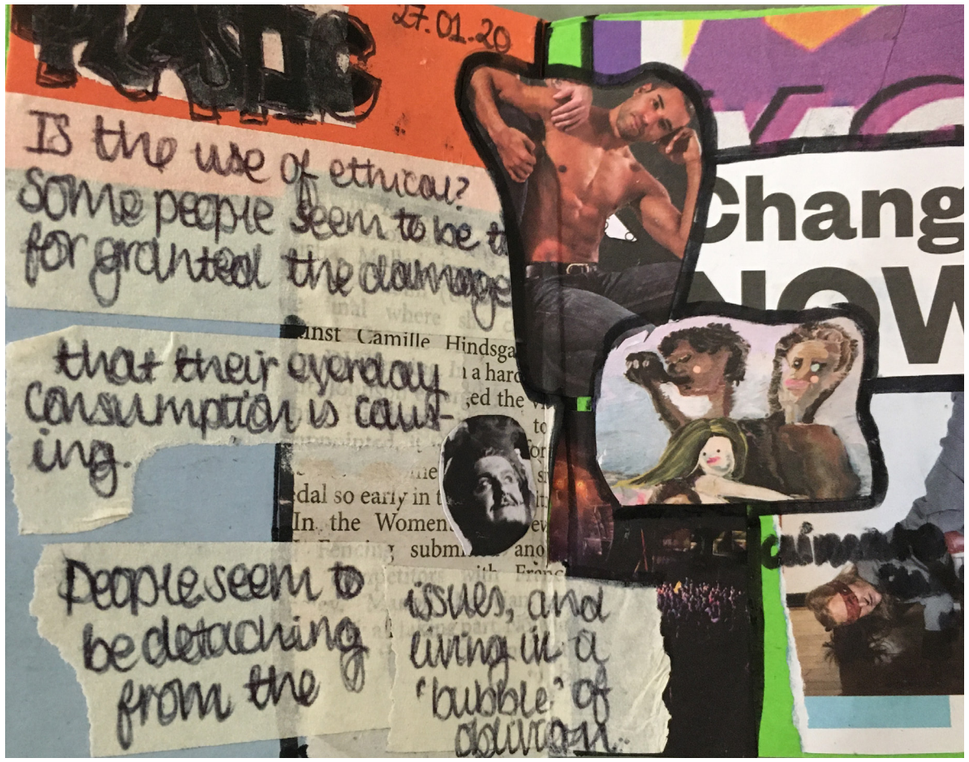


Photo credit: Science Gallery Dublin

Photo credit: Science Gallery Dublin

At LATRA Innovation Lab, we have taken zines on board with publics ranging from refugee minors in Lesvos to professional development for adults. The format has been very effective across three different projects. With zines, the concept and process are easy to grasp and anyone can make them.

Our workshops dealt with the overlap of three complex topics that were challenging to communicate on: EU values, UN sustainable development goals, and art & science. When we tried the zines, that almost solved the puzzle for us. It was easy for learners to produce something which can be understood. Learners tend to self-reflect and self-evaluate: they include private thoughts, different aspects of their lives and personalities. Little explanation is needed for them to get started. They also provide an attractive outcome to present at the end of the programme.

We had two female learners participate in one of the workshops who were not in school because of their background and could not read or write. The zine activity was a perfect way to engage with them. They were able to draw and convey their thoughts through a mediator who typed the notes up so they could be printed for the learners to stick them into the zine. It was amazing how quickly these vulnerable learners could jump into the process. They were very articulate, thoughtful and thorough. This was a real success considering how often these types of learners are marginalised by peers and teachers in school. On top of that, the level of content and how it was produced was impressive.

Aris Papadopoulos
CEO, LATRA, Greece

Photo credit: LATRA

In the Moment: Zines

Over the course of the zine workshops, SySTEM 2020 ethnographic researchers took notes on a number of key learning moments and instances of peer learning and support, highlighted by the following quotes:

"So, they can be anything? Anything we want?"

Learner to facilitator

"I love this, this is going to be so cool."

Learner to another learner about their own zine

Photo credit: LATRA

"Plastic is everywhere. We can't get away from it. It's in toothpaste."

One learner to the rest of their group

"I just want to chill and draw. This is going to be about that theatre workshop"

Learner to learner

"I can't really draw, so I think this is going to be mostly magazines and stuff [collage] but you'll see, you'll get the idea."

Learner to learner

"Plastic is good and bad. I don't think we need to be all negative about it. I don't think there's a wrong answer or a right one."

Learner to learner

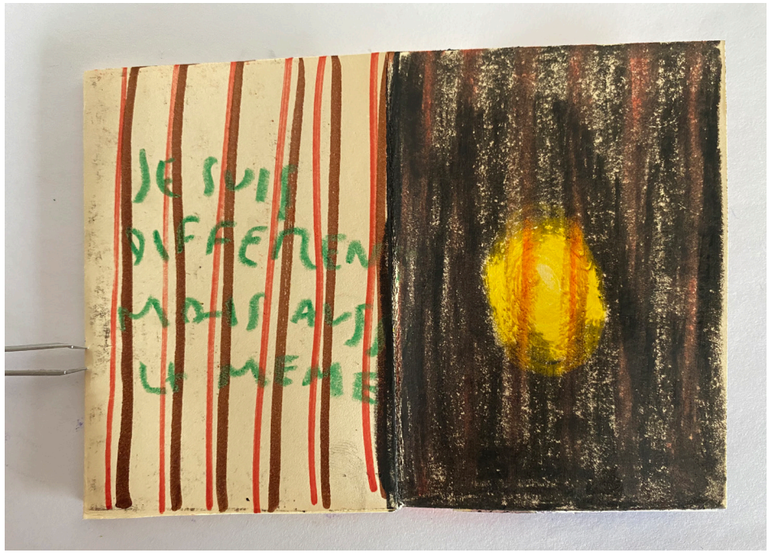


Photo credit: LATRA

"We don't have to worry about it, they said it's for us. Make it about whatever you want from the week"

Learner to learner

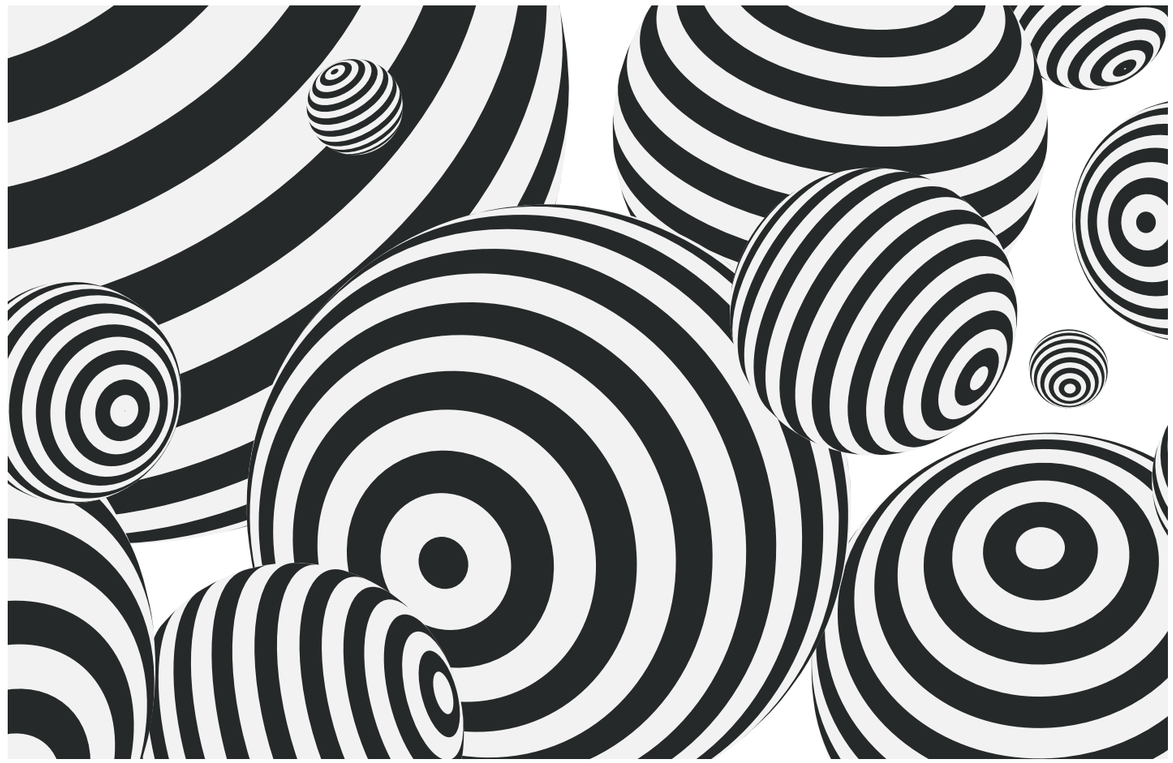
"It's fine, it doesn't have to look good.... It's to remember what happened"

Learner to learner who didn't seem to want to start their zine

Photo credit: Science Gallery Dublin

Photo credit: Waag

Recognition for Science Learning Outside the Classroom



SySTEM 2020 Toolkit of Frameworks, Tools and Practices

The SySTEM 2020 project investigated the use of credentials such as digital badges as a way to recognise the learning and the skills obtained in non-formal science education settings. We tested a digital badging tool based on the OpenBadges specification and the Badgr platform for digital learning credentials. Through trialling the tool with the partners, and surveying the young learners who took part, we found that learners were interested in paper or digital credentials for their activities, on the condition that these would bear some future utility. The learners saw the role of credentials as mostly social, to encourage a sense of satisfaction and an achievement to be shared with friends and parents or guardians, but was not seen as a potential resource to keep for use in the future. Because of the current lack of recognition of these credentials by external institutions, a science learning organisation may be unsure about using credentials.

In order to guide non-formal science learning organisations in deciding if credentials should be used in their context, SySTEM 2020 has developed a Credentialisation Diagnostic Tool. It is based on a checklist of criteria that were identified with the help of feedback from learners and concerns of the trial partners. The checklist contains questions such as: is there a social need to share the credential? or is there a formal need to share the credential? If the respondent answers yes to more than a certain number of questions then it could be advisable to develop and implement credentials.

We still don't know if credentialisation for non-formal science learning is something desirable in every case. However, it is still very important to focus on this topic because there is now a tension between market forces, where individuals are being hired on skills as opposed to degrees or formal education, and some historically disenfranchised communities that were typically excluded from formal education that see their skills as an opportunity to get access to the job market. On the flipside, hiring on skills can still be biased and standardised testing could be seen as protecting the disenfranchised. All in all, this is a question of design and of power. We see a pendulum swinging between "hard" and "soft" skills that has persisted over the past two centuries.

As a community we need to ask: who has the power to decide which skills are good for what? At the moment, I am not very convinced that there should be an emphasis on credentials in science learning spaces outside the classroom. There is a huge push for the commercialisation of credentials and I think we ought to wait and see what happens there.

Evangelos Kapros
Researcher, Science Gallery Dublin, Ireland

Photo credit: Waag

Through the Learners' Eyes

Meet the learners from 8 SySTEM 2020 locations

Since the conceptualisation of SySTEM 2020 in early 2017, it has always been a priority for us to place learners at the heart of the project. Throughout the project lifetime, young people have participated in hundreds of non-formal science learning activities. They debated ethics and artificial intelligence in Dublin, they explored the biodiversity of a local forest in Belgrade, and they built drones in Lesvos, to mention just a few. Most importantly, they have contributed to the production of the numerous tools and research outputs of the project. Each project partner invited two young learners aged between 18 and 20 to accompany them to a SySTEM 2020 co-design session in Helsinki in March 2019. The outputs of this co-design session served as the basis for much of the SySTEM 2020 research, in particular the Design Principles and Methods Toolkit.

"Over the past two days, the idea was to address three major subjects: inclusion, integration and assessment & recognition. And every group came up with one challenge for which they had a solution. My group came up with a learning committee in a local council. They try to pick people from diverse backgrounds in their community. Because no one knows the community as good as the community itself"

Rere Ukponu (19)
Dublin, Ireland

Learners tested every single research tool developed by the project, and their feedback and input shaped the direction of further work. For example, they tried out a chatbot interface as well as a more traditional online survey in the initial stages of developing the self-assessment tools, and voted in favour of the survey.

SySTEM 2020 learners have also contributed to eight "Learner's Perspectives" videos, a catalogue of their experiences related to out-of-school learning with a strong advocacy message for our field. These show how their involvement with out-of-school science education has allowed them to expand their knowledge and adapt to the changing world around them.

Photo credit: Science Gallery Dublin

What Now for Science Learning Outside the Classroom?

The 2020 OECD report "Back to the Future of Education"[3] presents a number of potential future scenarios for education - many of these show a marked reduction in the widespread reliance on traditional formal education as the primary mode of learning, and an enhanced role for non-formal learning within wider learning ecosystems. If such changes are on the horizon, the community of non-formal science educators must be supported with adequate resources, training and infrastructure to be able to respond appropriately and thrive in such a future.

Research-practice partnerships such as those developed through the SySTEM 2020 project must flourish over longer timescales to allow for adequate exploration of longitudinal effects of out-of-school STEAM learning, 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 and improve educational outcomes over time.

Non-formal STEAM educators are creative and innovative professionals, and the sites where they operate are varied across time and space. The way humans acquire and evaluate knowledge, and the way we learn is changing. It is time for governments and education systems across Europe to look to innovative models wherein STEAM learning happens as part of a broader learning ecosystem, structured to support all stakeholders, to be accessible to all communities, and to reward multiple ways of knowing. Such learning ecosystems will be enriched by tapping into the valuable network of science engagement professionals made visible by the SySTEM 2020 project.

3. OECD (2020), Back to the Future of Education: Four OECD Scenarios for Schooling, Educational Research and Innovation, OECD Publishing, Paris, https://doi.org/10.1787/178ef527-en

SySTEM 2020 in Numbers

25

Non-formal and informal learning mapped in 25 countries

1461

Organisations on the map

2890

Learners who engaged with our tools

22

Partner organisations

1544

Activities on the map

1410

Newsletter subscribers

37

Reports produced

5

Evaluation tools developed

1M+

People Reached

Reshaping Science Learning Outside the Classroom

Findings and Recommendations from SySTEM 2020

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