STEAM LEARNING ECOLOGIES

THE STEAM LEARNING ECOLOGIES CONCEPT WHITE PAPER

Deliverable 2.1

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D2.1 The SLEs Concept White Paper			
Work Package	SLEs Framework		
Lead Partner	Ellinogermaniki Agogi (EA)		
Author(s)	Georgios Mavromanolakis (EA), Sofoklis Sotiriou (EA), Pavlos Koulouris (EA), Evita Tasiopoulou (EUN), Barbara Quarta (EUN)		
Due date	31/03/2023		
Submitted date	30/03/2023		
Version number	3	**Status**	Final

Project Information	
Project number	101094648
Start date	01/01/2023
Duration	36
Call identifier	HORIZON-WIDERA-2022-ERA-01-70
Type of Action	HORIZON-CSA

Dissemination Level	
PU: Public	☒
PP: Restricted to other programme participants (including the European Commission)	☐
RE: Restricted to a group specified by the consortium (including the European Commission)	☐
CO: Confidential, only for members of the consortium (including the European Commission)	☐

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Quality Control	
Reviewed by:	**Review date:**
Laura Mentini (APRE)	16/03/2023
Francesca Santaniello (APRE)	16/03/2023

Revision history		
Version	**Date**	**Description**
0.0	28/02/2023	Draft version
1.0	08/03/2023	Pre-review version
1.1	16/03/2023	Post-review version
2.1	21/03/2023	Pre-templated version
2.2	27/03/2023	Post-templated version
3.0	28/03/2023	Final version

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Executive Summary

The SLEs White Paper is the first deliverable of Work Package 2. In this document we lay out the main foundational elements on which the SLEs approach and vision are based. We start by describing first the driving needs and aspirations, the policy context, and the relevant initiatives, and then continue with the constituent elements of the SLEs perspective. These include STEAM as the overarching approach, the open schooling as the main pillar and the living labs concept as key practice, altogether synthesized into local partnerships as learning ecologies. We discuss in detail each of these four aspects highlighting their key principles and characteristics.

In SLEs we envision and embrace STEAM education as an overarching approach across STEM subjects, the arts and all other disciplines that can greatly infuse and increase interdisciplinarity, creativity, problem-solving, critical thinking, integration and inclusiveness in school education and life-long learning. Using STEAM in education is about using subject integration coherently as an instructional approach for experiential and inquiry-based learning that provides multiple access points and diverse learning pathways for all learners to engage in the creative process and meet objectives in all subject areas. We believe that this manifold of access points and pathways is in its nature inclusive as it gives space for all to explore, freedom to follow unchartered regions and confidence to think differently.

We appraise and leverage this approach by embedding it in open schooling environment through living labs practice. This choice is a key opportunity enabler and multiplier by inherently offering a wide spectrum of access points for all involved. Our overall vision in SLEs is to fuse STEAM, open schooling environments and living lab practices within an empowering partnership based on local-level collaboration between formal, non-formal and informal science education providers, enterprises, and civil society. Because such fusion offers a unique opportunity to bridge the gap between formal education and business by developing an appropriate catalysing process in a connected science learning ecosystem where students encounter a wide range of learning experiences and are supported and mentored by experts and peers in ways that could lead to future opportunities in personal, academic, professional, and civic realms enabling new ways of thinking about societal challenges.

Along this line we put forward the concept of learning ecologies to offer a powerful new way to envision and develop impactful local open schooling partnerships as science learning continuum for all. We invoke pathways as a metaphor for thinking about ways to provide structure to learning experiences, about how they are inter-connected and inter-related and about how they allow or help learners to build upon them to pursue goals requiring extended engagement across multiple contexts and learning opportunities. In our view of a committed local partnership we want it to resemble a real ecological system in nature, which has the potential to initiate and generate in time a rich and robust complex system of relationships, interactions, pathways and opportunities of collaboration and development, which was neither prescribed nor predefined. In this respect when designing learning ecologies we should take into account that natural ecosystems both provide and require diversity, efficiency, adaptability and scalability. And so we should ensure that these features are present in our methodological approach. Regarding our methodology we postulate six key dimensions on which our methodological framework will be based and along which STEAM Learning Ecologies will be designed and developed accordingly, these dimensions are partnerships, mentoring, learner meaningful engagement, learner future choice, from research to enterprise, from enterprise to learning.

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Introduction

Europe's long-term capacity to innovate will decline if young people's interest for key science, technology, engineering and mathematics related studies and careers declines. Furthermore, in a society increasingly dependent on the use of knowledge, the acquisition of skills and competences that are becoming essential in all walks of life is also under threat, and will continue to be so, unless a radical change in people's, and especially in youth's, interest and aspirations is made. These are fostered and culminated through education and so the need for changing them is translating into developing and implementing innovative learning approaches, practices and methodologies along with policy support.

Following the publication of the Science Education for Responsible Citizenship report to the European Commission in 2015, several initiatives received European support to work towards integrating the innovative open schooling concept in science education (Hazelkom et al. 2015). Some have successfully produced wider methodological frameworks for the development of open schooling approaches in current school settings, with their emphasis varying from the reorganisation and central role of formal education, as in "Open Schools for Open Societies" (https://www.openschools.eu), to contributions by non-formal and informal learning spaces and practices, as in "Make It Open" (https://makeitopen.eu). Other projects have proposed specific methods and techniques for the re-engineering of school practice to accommodate innovative open schooling ideas and projects, the so-called living lab approach as in "Schools As Living Labs" (https://www.schoolsaslivinglabs.eu).

All this work has provided significant evidence that open schooling can indeed have a very positive impact on schools, generating favourable conditions for students' science learning, motivation and engagement. Based on this, the SLEs project aims to add its contribution by developing engaging open schooling-enabled science learning paths for all in learning continuum of formal and informal learning environments and enterprise by further emphasising on inclusiveness. SLEs proposes the powerful concept of learning ecologies as a vehicle for envisaging and realising impactful local open schooling partnerships as science learning continuum for all which will involve in and bring together all, rather than some, of the actors: formal, non-formal and informal education providers, as well as enterprises and the civil society. The goal is the creation of comprehensive partnerships in the form of interconnected knowledge ecosystems to give to all actors space, opportunities and motivation to take initiative and central roles in mutual learning and benefit.

SLEs methodological work starts with the current document, the SLEs White Paper, which on the one hand focuses on mapping the landscape, and on the other on laying out the main elements of the SLEs approach and vision. The former includes a thorough background study of the driving needs and aspirations, the policy context, and relevant initiatives. These correspond to sections 2.1, 2.2 and 2.3, respectively. Then follows the discussion of the constituent elements of the SLEs perspective, which includes STEAM as the overarching approach, the open schooling as the main pillar and the living labs concept as key practice, altogether synthesized into local partnerships as learning ecologies. The discussion on these four aspects is organized in sections 3.1, 3.2, 3.3 and 3.4 respectively. The document closes with the summary and a brief description of the next steps to follow towards transforming the SLEs conceptual vision to a methodological framework.

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Landscape Mapping

2.1 Driving Needs and Aspirations

Education being the way we organize teaching and learning throughout life has long played a foundational role in the transformation of human societies. It connects us with the world and to each other, exposes us to new possibilities, and strengthens our capacities for dialogue and action (UNESCO 2021).

Education plays a crucial role in personal and societal development. At the personal level, education provides individuals with skills, knowledge, and attitudes necessary for personal growth, career development, and socio-economic mobility (OECD 2022). Moreover, education helps individuals acquire literacy and numeracy skills, develop critical thinking, problem-solving, communication, and teamwork skills, and develop social and emotional skills that are essential for personal success (OECD 2019). Additionally, education promotes civic engagement, democratic participation, and social inclusion, as well as enhancing cultural awareness, tolerance, and understanding. At the societal level, education is a critical driver of economic growth, social development, and peace and stability. Education contributes to economic growth by equipping individuals with skills and knowledge necessary for innovation, entrepreneurship, and job creation (World Bank 2011). Education can also reduce poverty and inequality by providing individuals with opportunities for socio-economic mobility and social protection (OECD 2019). Moreover, education promotes social cohesion and stability by enhancing civic engagement, democratic participation, and peaceful conflict resolution (UNESCO 2021).

Education is essential to equip students with the necessary skills to thrive in 21st century societies. When it comes to STEM education, this constitutes a critical aspect of modern education that prepares students for the growing demand for STEM careers in the global economy. STEM education provides students with skills and knowledge in science, technology, engineering, and mathematics, which are essential for innovation, economic growth, and societal development. At the same time, STEM education can enhance critical thinking, problem-solving, creativity, and communication skills, which are necessary for addressing complex societal challenges such as climate change, energy security, and public health (Nguyen et al 2020).

STEM education also supports the promotion of gender equality and social inclusion by providing opportunities for under-represented groups to participate. Indeed, women and girls, persons with disabilities, and individuals from low-income and minority backgrounds are still under-represented in STEM related fields and careers. STEM education can therefore represent a powerful tool to address this disparity by providing inclusive and equitable learning environments that promote diversity, equity, and inclusion (OECD 2022).

In the first decade of the 21st century, it was suggested that arts and STEM subjects can be combined to obtain a synergic relationship with the purpose of improving creativity, engagement, and problem-solving skills (Bequette 2012). However, STEAM learning and teaching involves incorporating not just arts, but any non-STEM subject, such as literature, foreign languages, sports, within a framework, where the A represents arts and humanities, that combines real-world problem-based learning, multiple discipline integration, and problem-solving skills (Quigley 2017). To create and implement

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interdisciplinary STEAM activities for all subjects equally, it is essential to make meaningful and engaging connections between different subjects and to systematically explore how they can be combined effectively in collaborative project-based learning. A challenge to integrating a non-STEM subject is to not allow the A to be ignored while the activity focuses on STEM, or vice-versa.

The provision of high-quality STEAM education is quite complex and there are several aspects that need to be invested in:

- **Teachers:** Teachers are the backbone of any education system. They need to be well-trained, motivated, and adequately compensated to deliver quality education to students.
- **Curriculum:** The curriculum should be designed to meet the needs of the students and the requirements of the job market. It should be updated regularly to keep pace with changes in society and the economy.
- **Infrastructure:** Adequate infrastructure, such as classrooms, libraries, and laboratories, is essential for a good education system. The governments need to invest in building and maintaining such infrastructure.
- **Technology:** Technology is becoming increasingly important in education. Investing in technology such as computers, tablets, and internet access can enhance the quality of education and improve learning outcomes.
- **Access to education:** Education should be accessible to everyone, regardless of their socioeconomic status or location. The governments should invest in providing education to all, including those living in rural and remote areas.
- **Support services:** Students need support services such as counselling and mentoring. Investing in such services can help ensure that students receive the support they need to succeed.
- **Funding:** Adequate funding is critical for a good education system. The governments need to allocate sufficient resources to education to ensure that it is of high quality and accessible to all.

For all these aspects to advance, it is essential for all educational stakeholders to work together. Open schooling promotes this principle by facilitating collaboration among various stakeholders, including educators, learners, parents, industry professionals, and policymakers. By providing an open and inclusive platform for learning, open schooling helps to break down barriers to education and encourages students to explore new ideas and concepts, to gain exposure to real-world problems and work together to find innovative solutions. Additionally, by bringing together stakeholders from various backgrounds and industries, open schooling promotes the development of new partnerships and collaborations that can lead to new opportunities and helps to create a more dynamic and engaging learning environment for all involved (Hazelkom et al. 2015).

2.2 Policy Context

Societies around the world are becoming more inter-connected and inter-dependent and at the same time more competitive in acquiring and pursuing scientific knowledge and technological expertise that can provide advantages for creating new opportunities and innovative solutions that address the landscape of more complex societal challenges. For a society to be able to overcome these challenges it is essential requirement that all citizens have a better understanding of science and technology if they are expected to participate actively and responsibly in science-informed decision-

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making and knowledge-based innovation. In this context, science education policies play a significant role and become a leverage tool for long-term impact on economic growth and prosperity of societies.

Within Europe over the last decades there is a decrease in the numbers of students interested in, or actually pursuing science and technology related careers. Despite the fact that some progress has been made, there is still a strong gender gap in STEM related subjects. At the same time, it is inevitable that there is no considerable increase in science-based innovation or in cutting-edge knowledge-based entrepreneurship. As a result, Europe faces a shortfall in science-knowledgeable people at all levels of society and the economy.

These challenges clearly call for a strong and more coordinated effort to support education and training systems in Europe. In this context, the EU launched its renewed Digital Education Action Plan policy initiative to support the sustainable and effective adaptation of the education and training systems of EU Member States to the digital age (EC 2020).

In addition, gender equality remains a policy priority and in particular women's participation in STEM disciplines and professions is highlighted in the action plan. The importance of gender equality is also recognised in the Education 2030 Agenda, which sees education as empowering all genders (UNESCO 2016). The need to make mainstream education more inclusive, equal and diverse is also promoted through the UN Sustainable Development Goals, with Goal 4 to: "Ensure inclusive education and promote lifelong learning opportunities for all" (UN 2015).

A key moment highlighting the priorities and effort needed in reforming science education policy at European level comes in 2015 when the expert group on science education of the European Commission published its report on "Science Education for Responsible Citizenship" (Hazelkom et al. 2015). The report identifies the main issues involved in helping all citizens acquire the necessary knowledge of, and about, science, to be able to participate actively and responsibly in, with and for society, successfully throughout their lives. It also provides guidance concerning increasing the participation of enterprise and industry to science education policy and activities with the aim to equip citizens, enterprise and industry in Europe with the skills and competences needed to provide sustainable and competitive solutions. In its core is the necessity of a more responsive science education that can promote broader participation in knowledge-based innovation, in order to ensure sustainable societies into the future. In this sense, science education, research, innovation and practices must become more responsive to the needs and ambitions of society and reflect its values. They should reflect the science that citizens and society need and support people of all ages and talents in developing positive attitudes to science. Therefore, better ways to nurture the curiosity and cognitive resources of young learners are needed to enhance the educational process and better equip future scientists, researchers, engineers and other actors with the necessary knowledge, motivation and sense of societal responsibility to participate actively in the innovation process. Below are highlighted in brief the main recommendations of the report:

- Science education should be an essential component of a learning continuum for all, from pre-school to active engaged citizenship.
- Science education should focus on competences with an emphasis on learning through science and shifting from STEM to STEAM by linking science with other subjects and disciplines. Greater attention should be given to the value of all disciplines and how interdisciplinarity (STEAM rather than STEM) can contribute to the understanding and knowledge of scientific principles and solve societal challenges. In this way it is expected to achieve learning about science through other disciplines and learning about other disciplines through science but also strengthening connections and synergies between science, creativity, entrepreneurship and innovation.

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- Collaboration between formal, non-formal and informal educational providers, enterprise and civil society should be enhanced to ensure relevant and meaningful engagement of all societal actors with science and increase uptake of science studies and science-based careers to improve employability, competitiveness and innovation capacity.
- Encourage "open schooling" where schools, in cooperation with other stakeholders, become an agent of community well-being, where families and local communities are encouraged to become real partners in school life and activities, and where professionals from enterprise, civil and wider society are actively involved in bringing real-life projects into the classroom. Open schooling can promote partnerships between teachers, students, researchers, innovators, professionals in enterprise and other stakeholders in science-related fields, in order to work on real-life challenges and innovations, including associated ethical and social and economic issues.
- Promote partnerships that foster networking, sharing and applying science and technology research findings amongst teachers, researchers and professionals across different enterprises (start-ups, SMEs, large corporations) so that everybody learns and benefits from the involvement.

2.3 Open Schooling and STEAM Initiatives

The aforementioned recommendations and guidelines are gradually incorporated within Horizon 2020 and Horizon Europe Framework Programmes and more specifically in the funding actions of "Open Schooling and collaboration on science education" and of "Open schooling for science education and a learning continuum for all". The former action is aiming to support a range of activities based on collaboration between formal, non-formal and informal education providers, enterprises and civil society in order to integrate the concept of open schooling, including all educational levels, in science education. The latter, as a complementary action, foresees the creation of new partnerships in local communities to foster improved science education for all citizens and to contribute to a learning continuum for all. First are discussed initiatives from this action.

2.3.1 Open schooling for science education and a learning continuum for all

This action aims to support a range of activities based on collaboration at local level between formal, non-formal and informal science education providers, enterprises and civil society in order to integrate the concept of open schooling, including all educational levels, in science education. It targets the creation of new partnerships in local communities to foster improved science education for all citizens and to contribute to a learning continuum for all. It seeks to promote partnerships between for example teachers, students, scientists, researchers, innovators, professionals in enterprise and other stakeholders in science related fields. The aim is for these actors to work together on real-life challenges and innovations within local communities, engaging them in teaching and learning processes and to promote science education as part of local community development.

Projects funded under this action are expected to contribute to the following:

- Promote creation of new partnerships that foster networking, sharing and applying science and technology research findings amongst teachers, researchers and professionals across different enterprises;

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- Engage learners in meaningful real-life problem-solving situations, within education, the workplace and other learning environments;
- Encourage science studies and science careers by supporting cross-community networks of stakeholders to address issues such as the Green Deal, Health and Digitalisation;
- Increase female participation in science studies and science careers and deconstruct gender stereotypes;
- Foster, share and apply science and innovation research to different genres of enterprises e.g. start-ups, SMEs, entrepreneurs;
- Encourage mentoring across the different groups involved in the partnerships in order to take full advantage of science, technology, research and innovation;
- Encourage industry-funded innovation to become part of lifelong learning programmes.

In addition to SLEs, two more projects are funded in "Open schooling for science education and a learning continuum for all" action in 2022. These are "ICSE Science Factory" and "Learning Ventures for Climate Justice (LEVERS)".

ICSE Science Factory

Start/end date: 1/1/2023-28/2/2026 (https://cordis.europa.eu/project/id/101093387)

The ICSE Science Factory aims at establishing high-capacity cross-sectoral partnerships consisting of science researchers, science education researchers and non-formal education providers, supported by schools, enterprises and community institutions. The partnerships are strengthened and enlarged by the organisation of local conventions, where research findings are shared and applied. Local public fairs are also used to integrate wider communities in the scientific learning process through collaborative and interdisciplinary open schooling activities, on health, digitalisation and Green Deal. All activities include real-life problem-solving on issues relevant to society, decision-making and the concept of challenge-driven innovation. They are supplemented by systematic approach for encouraging mentoring across the partnerships and are complemented by a series of interactive career talks, focussing especially on female role models in science and on overcoming stereotypes.

Learning Ventures for Climate Justice (LEVERS)

Start/end date: 1/3/2023-28/2/2026 (https://cordis.europa.eu/project/id/101094825)

LEVERS aims to deliver a replicable model for expansive science learning through multi-stakeholder regional partnerships that collaboratively explore challenges and design science learning experiences to address local issues related to climate and biodiversity crises. Stakeholders from formal, non-formal and informal education across education levels, community organisations, research and innovation, industry, and government, will be supported to create climate justice projects offering meaningful real-world learning experiences. Capacity building and a mentoring programme will offer role models and guidance within and between regional learning partnerships, linking research and innovation with education.

2.3.2 Open schooling and collaboration on science education

This action targets the creation of new partnerships in local communities to foster improved science education for all citizens. It aims to support a range of activities based on collaboration between

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formal, non-formal and informal science education providers, enterprises and civil society in order to integrate the concept of open schooling in science education. It foresees that collaboration between formal, non-formal and informal science education providers, enterprises and civil society should be enhanced to ensure relevant and meaningful engagement of all societal actors in scientific domains and increase the uptake of science studies, citizen science initiatives and science-based careers, employability and competitiveness. It is expected that in the short term the development of partnerships between schools, local communities, civil society organisations, universities and industry will contribute to a more scientifically interested and literate society and students with a better awareness of and interest in scientific careers. In the medium term the activities are expected to provide citizens and future researchers with the tools and skills to make informed decisions and choices. Finally, in the long-term this action should contribute towards the objectives of increasing the numbers of scientists and researchers in Europe.

Projects funded under this action are expected to contribute to the following:

- Promote open schooling where schools, in cooperation with other stakeholders, become an agent of community well-being;
- Encourage families to become real partners in school life and activities;
- Actively involve professionals from enterprises and civil and wider society in bringing real-life projects to the classroom.
- Also involve relevant policy makers to encourage policy buy-in and the mainstreaming of good practices and insights into policies, and hence sustainability and impact beyond the lifetime of funding;
- Promote partnerships that foster expertise, networking, sharing and applying science and technology research findings across different enterprises considering gender, socio-economic and geographical differences.

Under action for "Open Schooling and collaboration on science education" the following eleven projects have been funded in 2018, 2019 and 2020 calls. Prior to them, in 2016, the "Open Schools for Open Societies" was the only funded project, which will be discussed in detail later in the document.

Science in the City: Building Participatory Urban Learning Community Hubs through Research and Activation (PULCHRA)

Start/end date: 1/9/2019-31/12/2022 (https://cordis.europa.eu/project/id/824466)

Strengthening science education through community partnerships

The PULCHRA project explores the open schooling concept in the theme "Cities as urban ecosystems". The aim of the project is to create new partnerships in local communities in order to support access to science education for all citizens and to expand opportunities for science learning in formal and informal settings. Schools partner with local communities, local industries and professionals, and in cooperation with all stakeholders become agents of community well-being, taken that the theme to be explored encompasses the natural environment, the built environment and the socio-economic environment in cities.

Science education for action and engagement towards sustainability (SEAS)

Start/end date: 1/9/2019-31/8/2022 (https://cordis.europa.eu/project/id/824522)

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Advancing scientific literacy for responsible citizenship

The SEAS project develops and makes use of open-schooling networks to promote responsible citizenship via education by supporting the development of scientific literacy and 21st century skills. As part of these networks, and drawing on principles of inquiry-based science learning for transformative engagement, students are given the opportunity to engage in real-life, complex sustainability challenges that are identified together with stakeholders in the local community. SEAS enhances opportunities for students and citizens, developing deeper interest in science and inclusive scientific literacy. This is done by providing facilitation tools and methods for the identification and implementation of sustainability challenges in the participants' local communities through which students collaborate with families and stakeholders from civil society and industry and become agents of community well-being.

Partnerships for pathways to Higher Education and science engagement in Regional Clusters of Open Schooling (PHERECLOS)

Start/end date: 1/10/2019-30/9/2022 (https://cordis.europa.eu/project/id/824630)

Introducing children and youth to academic research

PHERECLOS builds upon the theory of science capital and the concept of children's universities. The aim is to spread knowledge outside the academic environment with considerable profit for the society and the economy. Universities through their engagement with children and young people, become intermediaries between various actors in the educational and social landscape. As translators of the concerns, messages and knowledge of other parties including business and industry, the state, civic society organizations etc., they help to dismantle institutional boundaries of universities towards a wider society. The PHERECLOS project intends to bring together schools and academic actors, as a way to develop collaborative educational environments and establish local education clusters. Such clusters will work as agents of innovation in education and play a fundamental role in advancing critical thought, decision-making, competitiveness and sustainable growth among children and youth. The local education clusters, supported by a peer mentoring programme, will also act as incubators enabling a dialogue between various actors and help to set up joint activities catalyzing STEAM engagement in formal and non-formal education, and to develop collaborative learning environments for schools.

Open Science Hub Network: Empowering Citizens through STEAM Education with Open Schooling (OSHub)

Start/end date: 1/10/2019-30/9/2022 (https://cordis.europa.eu/project/id/824581)

New Open School hubs to developing STEAM education

Open Science Hub Network is a European network of community spaces in which schools act as intermediaries of collaboration between civil society, local enterprises, research institutes, social innovators and community at large by providing science, technology, engineering, art and mathematics (STEAM) learning opportunities. OSHubs engage communities, including civil associations and families, in tackling local challenges using inquiry-based science education and Responsible Research and Innovation (RRI) concepts and principles. The main vision is to inspire, empower and engage citizens from all age groups to bring STEAM education to the communities as a tool for their sustainable development

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Schools as Living Labs (SALL)

Start/end date: 1/9/2020-31/8/2023 (https://cordis.europa.eu/project/id/871794)

Living labs for science education in schools

The SALL project aims to introduce the "living labs" methodology in schools as a novel technique for the development of open schooling activities linked to science learning. The living lab is a fresh approach that lets students use outdoor spaces for research and demonstration projects, independently driven projects and new contexts for research and sustainability. It has the potential to change the education process, by enhancing engagement, inspiration and by bringing a holistic attitude. The project engages school communities, research institutions, science museums and centres and spaces of informal learning in dialogue, mutual learning and exchange. Together they construct the living labs schooling methodology which will be implemented and evaluated in the real-life system, demonstrating its ability to radically change the scene for science education programmes in schools.

Inclusive open schooling through engaging and future-oriented science (CONNECT)

Start/end date: 1/9/2020-31/8/2023 (https://cordis.europa.eu/project/id/872814)

Facilitating adoption of open schooling for science education

CONNECT focuses on developing and proposing an inclusive, sustainable model for enabling more secondary schools to adopt "open schooling" by embedding science-action gamification projects in the core curriculum. This is achieved through the use of approaches of participatory science with families, universities and enterprises to increase students' interest and confidence with science in life. Its starting point is the fact than in most educational systems around Europe open schooling activities for science education are available for limited groups, mainly in the form of extracurricular activities or reserved for the most talented students. However, it is important to ensure all young people become more scientifically literate by prioritising and facilitating inclusion in education, allowing students to benefit from learning experiences that meet their needs. It is especially necessary to prepare secondary schools to prepare students for future careers. To make open schooling inclusive and widespread in science education, this initiative therefore aims to practically address the following key questions: how can open schooling increase the value and priority of partnership activities and reduce the barriers to entry so more schools are willing and able to adopt them; how can open schooling facilitate the interaction between all partners (science professionals, teachers, students and their families) resulting in effective learning experiences linked to research and innovation; how can open schooling make science careers more inclusive by giving disadvantaged students more experience and insight into professional STEM jobs, whilst being supported by professionals and their families.

Meaningful Open Schooling Connects Schools To Communities (MOST)

Start/end date: 1/9/2020-31/8/2023 (https://cordis.europa.eu/project/id/871155)

Partnerships to promote science competences

The MOST project aims to support school students and citizens to develop science knowledge, transversal skills and competences by arranging meaningful engagements between schools and their communities. It opens up formal science education and establishes partnerships between schools and their communities (families, science education providers, citizens, businesses, etc.) to

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work jointly on environmental school-community-projects. Planning and implementation involve all relevant areas, such as for instance formal and non-formal education, research practice, policy, innovation-driven businesses and society as both benefactor and innovation drivers. The collaborations between these actors in school–community projects through an educational research-based approach is expected to offer collective benefits and learning impacts that raises interest in science, scientific literacy and environmental responsibility. Therefore, these participatory projects will directly respond to the needs and values of those involved, benefit the communities as a whole and make schools agents of community well-being.

Make it Open

Start/end date: 1/10/2020-30/9/2023 (https://cordis.europa.eu/project/id/872106)

Open schooling through maker education

The Make it Open project aims to promote science education in schools and to generate synergies between the areas of science, creativity, entrepreneurship and innovation by bringing together experts in maker education with enterprises and civil society organisations. The project will create open schooling hubs where school students work on solving community challenges using tools and approaches from maker education. The project's goal is to bring together inquiry-based approaches of science education and creative classroom approaches of the maker movement in an accessible and actionable framework. It will offer tools for collaboration between formal, non-formal and informal educational providers, enterprise and civil society, and support schools in becoming agents of community well-being where families are encouraged to become real partners of the learning process. The project will also work closely with teachers and school administrators to set up their own vision for open schooling, and tailor a model which will work within their context, needs and opportunities, thus maximising the potential for successful uptake.

Partnerships for science education (PAFSE)

Start/end date: 1/9/2021-31/8/2024 (https://cordis.europa.eu/project/id/101006468)

Teaching public health science in pandemic times

The PAFSE project aims to engage schools, universities, enterprises and non-formal education providers in building science clusters that boost young people's awareness of public health challenges, protective factors and patterns of risky behaviour, and the role they can play in their community preparedness. School-based activities will contribute to students' and citizens' literacy concerning public health threats that need to be approached by concerted action, with a focus on epidemics. Challenges such as child obesity, chronic illness, climate change and vaccine hesitancy will be included in the educational provisions. PAFSE will strengthen populations' literacy and mitigate risks, having students play a central role as public health ambassadors, early adopters and spreaders of scientific knowledge. The project will contribute to community preparedness to reduce the risk of communicable disease and epidemics. It will do so by establishing partnerships between schools, universities, non-formal education providers, enterprises and civil society organisations. Such collaboration is expected to enrich STEM education by including public health issues, an understanding of microbes and zoonosis, and the value of disease prevention measures in protecting communities. The PAFSE's overall approach aims not only to increase the global population awareness and preparation to deal with future epidemics but also to be applicable in addressing other public health and global challenges, such as child obesity, or climate change issues.

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Multiplayers' Partnerships to Ensure Meaningful Engagement with Science and Research (MULTIPLIERS)

Start/end date: 1/11/2021-31/10/2024 (https://cordis.europa.eu/project/id/101006255)

Promoting student interaction with science professionals

The MULTIPLIERS project aims to facilitate the transition of schools into innovative and open collectors of new ideas, practices, and scientific approaches. Schools should be able to offer to the communities in which they are embedded a space for open, inclusive and inquiry-based learning on science topics which have an impact on citizens' lives. This will be achieved by establishing multiplayers' partnerships involving schools, families, civil society organisations, informal education providers, policy-makers, the media and a wide range of science institutions. These open science partnerships and communities will jointly select socio-scientific issues to be tackled and develop science projects with real-life challenges as starting points to be implemented in schools. Students will interact with a broad spectrum of science professionals and be involved in data collection and decision-making processes. Via open community events, they will then share and rethink their findings and experiences, liaising with families and society, thus acting as science multipliers.

Creating Organisational Structures for Meaningful science education through Open Schooling for all (COSMOS)

Start/end date: 1/1/2022-31/12/2024 (https://cordis.europa.eu/project/id/101005982)

Making science education meaningful

The COSMOS project aims to create new partnerships within communities that can foster science education for all citizens. The goal is to encourage an 'outwards' mode of engagement between schools and communities creating meaningful science education experiences that transcend the walls of the classrooms and the schools. Specifically, the project will support the creation of communities of practice consisting of non-formal and informal education providers, enterprises, families and other stakeholders. It will also introduce new or strengthen existing organisational structures within schools, ensuring the engagement of all societal actors and enhancing students' interest in science and science careers by working closely with science teachers, providing opportunities for professional development, networking, collaboration and capacity building. It uses socio-scientific inquiry-based learning as a pedagogical means for opening up schools to their communities through a transformative process, aiming to create new partnerships within communities that can foster science education for all citizens, irrespective of gender, ethnicity or cultural background. Its goal is to develop an open schooling environment that combines key pivotal elements of innovative constructivist pedagogy, teacher education, and methods of change of school organisational culture, with the ultimate goal of transforming and opening schools from an 'inwards' to an 'outwards' mode of engagement in, with and for their communities.

All EU policy initiatives on science education from 2015 to 2022, including experts' report, action calls and funded projects are grouped accordingly and are shown in Fig. 1. If we want to select some key developments along this timeline we can start with OSOS which paved the way by proposing, implementing and validating a model for organisational change of schools in order to become open schooling environments. This to large extent informed the methodology of subsequent projects which applied open schooling to various focus areas, for example to address challenges in cities and urban ecosystems (PULCHRA 2020), or in general to environmental problems and to real-life complex sustainability challenges (SEAS 2022).

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In addition, various models for the establishment and implementation of more focused open schooling partnerships were also developed and tested, for example to bring together schools and higher education in the case of Children's Universities (PHERECLOS 2022) or to establish open schooling hubs and networks in communities that traditionally do not engage with research and innovation due to various barriers, geographical location, socio-economic status, or ethnic minority group background (OSHubs 2022). Complementary to these we highlight also the framework developments with focus to generate synergies in the areas of science, creativity, entrepreneurship and innovation, for example by bringing together experts in maker education with enterprises and civil society organisations (MakeItOpen 2022) or by adopting practices utilised in enterprises to foster innovation (SALL 2020). More recent advances building on previous results include embedding gamification approaches (CONNECT 2020), focusing on inclusiveness through socio-scientific inquiry-based learning (COSMOS 2023) or concentrating on public health challenges and the role open schooling can play in community preparedness (PAFSE 2023).

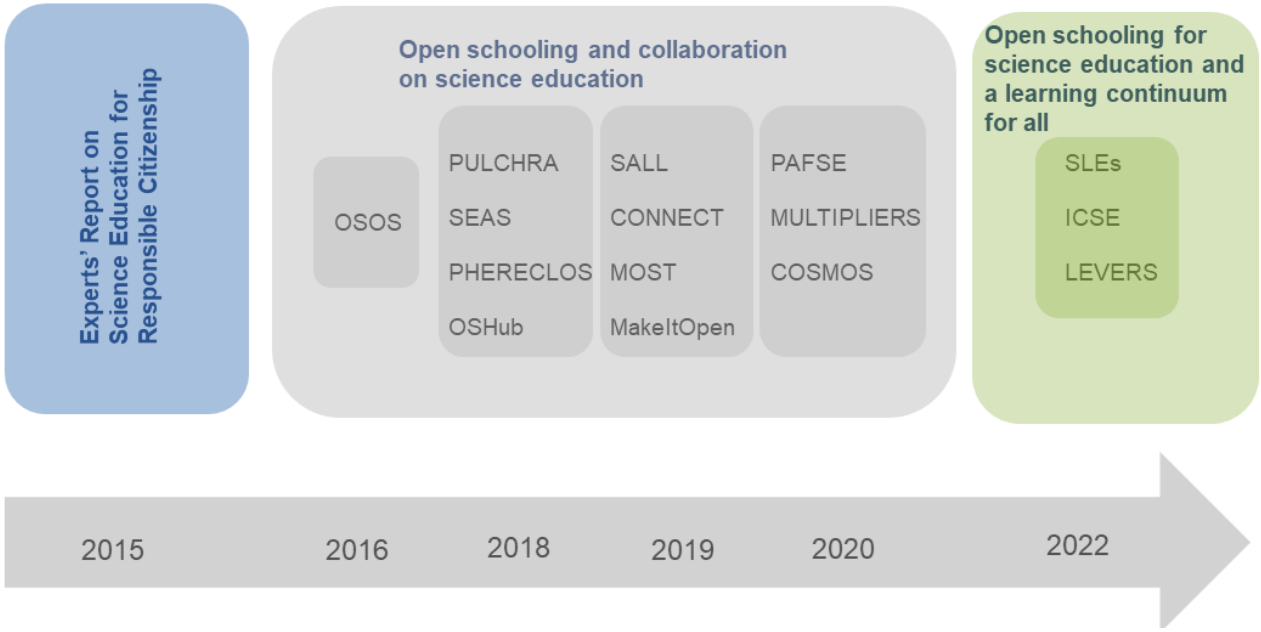

Figure 1 : Timeline of key EU policy initiatives on science education including experts' report, action calls and funded projects

All projects described herein have set their own priorities, objectives and focus of actions, forming a wide landscape in which SLEs will also contribute. Opportunities for synergy, interplay and cooperation can be already identified based on available information and resources and new ones will emerge as project works develop. At this stage of the project, within SLEs scope we consider the following key areas of interest, namely, open schooling methodology, STEAM activities, inclusive approaches, and enterprise partnership engagement. These are tabulated in Table 1. The colour scheme of the table distinguishes the different key areas in each project according to a level of interest for SLEs project. The colour scheme from lighter to darker tone refers to a range from moderate, moderate to high, and high. This visualization can be seen as an initial effort to map and express SLEs' interest at the level of consultation, adoption or adaptation of relevant approaches

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and methodologies, or interest on taking benefit from findings and experiences with respect to barriers and enablers. By no means this categorisation refers to the quality of related work in each project or its outcomes.

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Table 1 : Key areas of interest for synergy, interplay and cooperation within the scope of SLEs and other projects. (The colour scheme from lighter to darker tone categorises them in interest range from moderate, moderate to high, and high).

	Open schooling methodolog	STEAM activities	Inclusive approach	Enterprise engagemen t
Inclusive open schooling through engaging and future-oriented science (CONNECT)	1	1	3	1
Creating Organisational Structures for Meaningful science education through Open Schooling for all (COSMOS)	2	1	2	1
Make it Open	2	3	1	1
Meaningful Open Schooling Connects Schools To Communities (MOST)	1	1	1	1
Multiplayers' Partnerships to Ensure Meaningful Engagement with Science and Research (MULTIPLIERS)	1	1	2	1
Open Science Hub Network: Empowering Citizens through STEAM Education with Open Schooling (OSHub)	2	2	1	1
Partnerships for science education (PAFSE)	2	1	1	1
Partnerships for pathways to Higher Education and science engagement in Regional Clusters of Open Schooling (PHERECLOS)	1	2	1	1
Science in the City: Building Participatory Urban Learning Community Hubs through Research and Activation (PULCHRA)	2	1	1	2
Schools as Living Labs (SALL)	3	2	1	2
Science education for action and engagement towards sustainability (SEAS)	2	1	2	1

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Conceptual Synthesis and Vision

The constituent elements of the SLEs perspective include STEAM as the overarching approach, the open schooling environment as the main pillar and the living labs concept as key practice, altogether synthesized into local partnerships as learning ecologies. In the following sections, we discuss in detail each of these aspects highlighting their key principles and characteristics.

3.1 STEAM as Overarching Approach

SLEs envisions and embraces STEAM education as an overarching approach across STEM subjects, the arts and all other disciplines that can greatly increase interdisciplinarity, creativity, problem-solving, critical thinking, integration and inclusiveness in school education and life-long learning. In this section we first discuss the STEAM movement from a wider perspective and then underline its aspects which lie at the core of the SLEs project and its objectives.

The acronym STEM was introduced early in the 21st century as a way to refer to careers, initiatives and curricula focused on science, technology, engineering and mathematics, emphasizing their importance in a knowledge-based and technology-driven world. Efforts to emphasize, enhance or integrate STEM as an interdisciplinary approach into educational frameworks first began in the US and soon expanded also in other countries across Europe and around the globe.

With respect to transversal competencies, the OECD, the European Commission, the US National Academies and Research Council, and other policy organisations at national or international level, emphasize four primary skill areas that are commonly identified and that are widely recognised as necessary to thrive in the 21st century societies: Critical Thinking and Problem Solving; Communication; Collaboration; Creativity and Innovation (OECD 2018; EC 2018; EC 2019; NGSS 2013; NRC 2012; Innovation Unit 2013).

As the education world continues to explore new strategies to equip students with these skills and the knowledge they need to be successful innovators and creators in the 21st century, there has been a growing emphasis on STEAM rather STEM related learning. STEAM as a holistic approach aims to bring together all critical disciplines to create an inclusive learning environment that encourages all students to participate, collaborate, solve problems, innovate and co-create, as they would need to do in a 21st century working and living environment. As opposed to traditional models of teaching, the STEAM framework blurs the lines between disciplines in order to encourage higher levels of creativity and engagement when it comes to problem solving and innovative thinking.

STEAM is a progression of the original STEM acronym, plus one additional element, A, referring to arts or all other non-STEM subjects. Their integration into STEM learning allows educators to expand the benefits of hands-on education and collaboration in a variety of ways that aim at promoting creativity and curiosity as the core ingredients that enhance learners' continued educational and personal development. Hence STEAM is set to forearm learners with effective soft - creativity and critical thinking skills - along STEM hard scientific skills. By adding a focus on helping students develop a creative mindset, and other related skills like collaboration and communication, education can provide students with higher opportunities to be successful in personal lives or professional settings requiring problem-solving skills.

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The STEAM movement should not be misunderstood as an attempt to undermine or take away from STEM or its subject areas. On the contrary the main idea is to enhance the overall framework by invoking a greater sense of creativity which can entice students who might not otherwise consider a STEM career to do that. For example, by adding a focus on the arts and integrating all other disciplines in a creative way this approach has the ability to make students more interested, engaged and well-rounded and at the same time it opens them up to a vast number of new opportunities. In some way the idea is to teach students that they don't have to be only analytical or only creative, but they can be both. In other words, to be successful in solving almost any problem they face now or in the future, one must be both an analytical thinker and a creative innovative thinker.

Another important aspect of the STEAM approach is that students aren't just taught a specific subject matter, instead they're taught how to ask and investigate questions, how to be innovative and search for solutions, and how to create. This allows them to develop the ability to approach any situation with an open, critical and creative mindset.

This transformative shift from content-based teaching towards process-based learning is one of the key recommendations of the "Science education for responsible citizenship" report (Hazelkom et al. 2015). This report highlights that science education should focus on competences with an emphasis on learning through science and recommends shifting from STEM to STEAM by linking science with other subjects and disciplines. Traditionally STEM or in general science education is regarded as focusing on learning in the context of science and mathematics. However, there can be a distinction between knowledge of a science subject and knowledge about science. The former includes understanding fundamental scientific concepts and acquiring content knowledge. The latter, knowledge about science, includes "understanding the nature and process of science as a human activity and the power and limitations of scientific knowledge" (OECD 2009; OECD 2019).

This key distinction between content acquisition and process-based learning is crucial as the world faces challenges of greater scale and complexity like climate change, energy transition, food and water security, human health and healthy living, or sustainable growth and development. And understandably it is becoming more important because these major societal challenges transcend borders and disciplines at multiple levels and necessitate novel ways of thinking and new methods of organization in order to address and solve them effectively. Novel ideas, innovation and creative solutions often emerge at the borders of disciplines and new ways of thinking can come not only from fundamental science, applied research or technological progress but also through changes in the way we view and do things, think about or organize priorities and interlink facts and visions. In this context social innovation depends on the ability to resolve issues, not in isolation or within a single field of knowledge, but instead, in a broader perspective, in relationship to others and in partnership with multiple actors (Blackwell 2009). In other words, it depends on being able to collaborate, listen to the ideas of others, think critically, be creative and take initiative to solve problems and take decisions. Therefore, making meaningful connections between STEM and all other disciplines, which is precisely what SLEs encompasses and advocates as STEAM learning, pushes beyond the boundaries of science to embrace the creative potential of linking the arts, scientific inquiry and innovation (Wilson 2002). This can occur for example through engaging with the arts or other non-STEM disciplines either as starting point or being involved in designing and making within STEM subjects. Similarly, involving subjects from humanities and the social sciences help to understand the wider perspectives and implications that science and technology have in societies and civilizations across time but also to envisage and reflect on possible futures.

As already mentioned, innovative ideas and creative solutions often emerge at the interface between disciplines and can involve different societal actors to bring in or link to diverse experiences, needs and problems. It can also involve different learning settings. Learning can happen in formal, non-

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formal and informal spaces, at home, in the community and in activities linked to enterprises. This idea touches upon the open schooling concept which will be discussed later on. At this point it should be emphasised that SLEs appraise STEAM approach as one of open schooling main enablers and opportunity multipliers by inherently offering a wide spectrum of access points for all involved. By linking the arts, humanities and other subjects with science, technology, engineering and mathematics it can bring learners, scientists, engineers, entrepreneurs, artists, altogether into dialogue to offer the broadest range of insight for mutual learning, experimentation, exploration and innovation (Wilson 2002). This also nurtures the notion of responsible and active citizenship and contributes to it at local, national, European and global level.

It is SLEs' core belief that using STEAM in education means supporting subject integration coherently as an instructional approach for experiential and inquiry-based learning. Doing so provides multiple access points and diverse learning pathways for all learners to engage in the creative process and meet the objectives in all subject areas. This manifold of access points and pathways is in its nature more inclusive as it gives space for all students to explore, freedom to follow unchartered regions and confidence to think differently.

In SLEs we regard that our main goal of having STEAM-based learning is to help students develop the skills they need to be successful in the future regardless of the specific path, career or role they choose to follow. It is now more than ever critical that students acquire as early as possible and possess as thoroughly as possible this aforementioned set of key skills that will allow to adapt to an evolving and rapidly changing environment.

Hence, SLEs envisions to instil in its pedagogical approach the following key directives with respect to STEAM:

- STEAM is an integrated approach to learning which requires an intentional connection between learning objectives or standards, assessment and lesson/learning pathway design and implementation.
- Scientific inquiry, collaboration and an emphasis on process and project-based learning are at the heart of the STEAM approach. STEAM is about acquiring key competences rather than simply learning facts.
- STEAM experiences involve as many subjects as possible ranging from science, technology, engineering, mathematics, arts and other disciplines to be taught and assessed in and through each other.
- Utilizing and leveraging the inherent creative and inclusive nature of the arts themselves is essential to an authentic STEAM initiative.
- STEAM education is an approach to learning that uses science, technology, engineering, mathematics, arts and other subjects as dynamic access points for engaging and supporting or guiding learners in inquiry, dialogue and critical thinking processes.
- STEAM facilitates learning environments that are authentic, diverse, dynamic, meaningful and relevant.
- Using STEAM education aims to help students engage in experiential learning, persist in problem-solving, embrace collaboration and work through the creative process. In such a way, students may become not only the innovators and leaders of the 21st century but also inspiring educators, scientists, engineers, responsible citizens and life-long learners.

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3.2 The Open Schooling Pillar

In the previous section we discussed how we envision STEAM approaches can facilitate the development of innovative ideas and creative solutions that emerge at the interface between disciplines and can involve different societal actors to bring in or link to diverse experiences, needs and problems. We mentioned that it can also involve different learning settings as learning can happen in formal, non-formal and informal spaces, at home, in the community and in activities linked to enterprises. This is the core element of the open schooling concept which within SLEs is further generalized as being an environment that promotes partnerships between different societal actors and the local community with a view to engaging them in the teaching and learning processes but also to promote education as part of local community development. An open schooling learning environment helps and engages learners to apply learning to real-life problems and find effective solutions. They are inspired to be responsive, innovative and entrepreneurial in their approach to learning, to generate ideas and applying them to solve problems and to create sustainable responses to community's and in general to society's challenges (Price 2013; Covay 2010; Mueller 2015).

In this context open schooling, as openness of education to local communities and to society in general, is a pillar of the pedagogical design and vision of SLEs. Essential elements of the open schooling concept were firstly developed in the "Open School for Open Societies" (OSOS) EU funded project, implemented between 2017 and 2020 (https://cordis.europa.eu/project/id/741572). The project succeeded in introducing and testing an open schooling model with 1000 schools across Europe. It is in SLEs plan and strategy to closely collaborate with OSOS in order to capitalize on its outcomes, experiences and findings, and to re-utilize where possible tools and concepts (e.g. community support platform, authoring tool) which were developed and successfully deployed during its implementation.

In the framework of SLEs, we define an "open school", that adopts the following main characteristics:

- Welcomes, encourages and promotes collaboration with non-formal and informal education providers, initiatives, parents and local communities to ensure the engagement of all societal actors. In this respect, the school entity is not considered as an isolated self-contained closed system but an active core component, to some extent autonomous and dynamic, in active interaction with the activities of out-of-school stakeholders.
- Becomes an agent or central point of community well-being. SLEs aims to support schools, teachers and their students to develop educational projects that are proposing solutions to the needs and challenges of their local communities. The main approach will be to challenge and encourage students to explore themselves the notion of well-being by identifying and expressing what matters to them, what bothers them, what they can change or influence, how they can contribute or serve to societal issues. In this process, it is expected that not only students feel more engaged and empowered, but that they also develop and foster an attitude of responsible citizenship for the years to come.
- Promotes collaboration and partnership that foster expertise, networking, sharing and applying knowledge, research findings that bring real-life problems or challenges related projects to the classroom. Within SLEs, cross- sharing and co-creation will be enhanced and facilitated thus further supporting the developments of 21st century competences through creative problem solving, discovery, learning by doing, experiential learning, critical thinking and creativity.
- Focuses on or promotes the effective engagement of diverse actors involved. This characteristic builds on the general notion of knowledge capital of schools' communities and its two-way transfer, exchange and diffusion. In other words, knowledge or awareness

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acquired by students' projects developed in school is transferred to families, parents, communities and other stakeholders and on the other way around their external experience and expertise influence effective change. On this matter, OSOS implemented a strategy with four courses of action to materialize effective parental engagement in the projects that will be developed by: 1. School planning, 2. Collaboration, 3. Monitoring and 4. Sustained improvement (Sotiriou et al. 2017).

It is natural to expect that the schools that will express interest in participating in SLEs may not have developed these characteristics at the same level. Thus, SLEs will propose, design and implement educational activities that will be accompanied by practical guidance or support mechanisms. This way, the incubation of a change cycle will be supported in order for schools and teachers to facilitate the process of acquiring or developing the aforementioned characteristics.

With respect to the design of educational activities in open schooling, the main pedagogical approach adopted by SLEs is project-based teaching and learning. We consider also implementing inquiry-based methodology which is also utilized by STEM teachers for effective learning. One may draw distinctions between project, inquiry or problem-based learning, however in practice the differences amongst these approaches are minor. Great projects grow from inquiries in order to solve problems. Students find them highly engaging because they stem from working on issues that are meaningful to them and their families or communities. Learning begins with a problem to be solved, and the problem is posed in such a way that students need to gain new knowledge before they can solve the problem. Rather than seeking a single correct answer, students interpret the problem, gather needed information, identify possible solutions, evaluate options and present conclusions. The whole process gives students the opportunity to connect to real-life/real-world challenges, work across disciplines, learn to function and collaborate in teams, communicate their findings and solutions, and engage with their peers, experts and communities.

An enabling facilitation model is the four-step process, named "Feel-Imagine-Create-Share", as it was first developed by the "Design for Change" movement and has been accordingly adapted by the OSOS project. This will be the main process that SLEs plans to adapt and propose to teachers and students, more generally to educators and learners, to develop their projects along with a generic inquiry-based pedagogical model (Pedaste et al. 2015).

Design for Change (https://www.dfcworld.com), in short DFC, is a global movement that aims to empower students and the youth to say "I CAN" and inspire others by telling their own stories of change. The programme has introduced its unique curriculum in over 30 countries worldwide and promotes design process as a way of encouraging students to create and develop solutions in their communities and to put into practice their own ideas to change the world starting from their own environment. The main concept is that design-thinking, a solution-based and user-centered approach to tackling problems, allows students to become active learners who guide their own learning process. Since its founding in 2009, DFC has worked to introduce design-thinking in the education sector in a way that is accessible for children of all ages. DFC weaved students' own stories back into education by designing a year-long curriculum. Students begin to develop the design mindset while engaging in real-world problems, in turn activating and developing skills and attitudes, such as a sense of well-being, problem-solving, and other 21st century skills. The curriculum is designed to be plugged into existing school calendars and enhance academic learning. In the learning-service, the students identify in their immediate environment a situation with which they are committed, developing a solidarity project that brings knowledge, skills, attitudes and values into play. It is an educational practice in which children learn while acting on real needs in order to improve it. Every year, teams from around the world submit social change projects using the Design for Change framework. An Ambassador Team is selected to attend an all expenses trip to the DFC Global

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Conference that brings together teams from across the world to share and celebrate their projects, and most importantly, inspire others.

DFC developed and implemented a model or standard four-step process to guide students to develop their projects. The steps to follow are:

- Feel: Students identify problems in their classrooms, schools, and communities. Students observe problems and try to engage with those who are affected, discuss their thoughts in groups, and vote on an idea.
- Imagine: Students envision and develop creative solutions that can be replicated easily, reach the maximum number of people, generate long-lasting change, and make a quick impact.
- Do: Students develop a plan of action to promote change. This includes planning, implementing, and later recording the process.
- Share: Students submit their stories to DFC through text, photos, video, or slideshows and are encouraged to do so with other schools in the community and local media, as well.

In this way DFC curriculum has greatly simplified design thinking principles for children leading to widespread uptake. The framework of Feel, Imagine, Do and Share builds empathy in children, for them to engage as active participants in their communities. It redefines failure as prototyping and gives them the confidence to be innovative and find creative solutions for problems that bother them. Children become change makers. Teachers are able to experience the capabilities of their own children as they listen to their voices and ideas. Feel gets children to empathize and engage with a problem, they imagine a solution and do the act of change. Through sharing their story, they inspire others.

As a part of the DFC programme, children have chosen to tackle a number of issues plaguing their communities, such as waste management, school infrastructure, health awareness, special needs, personal hygiene, learning aids, and gender equality. DFC works with all actors: with both private and government-run schools as well as NGOs that operate in rural or more remote areas. The program is free for schools and run individually at the country-level. While sponsors contribute initial funding and materials, each program runs independently. DFC conducts design thinking workshops for teachers, provides technical support with websites and the online community, and selects and shares inspiring stories from participants. These are usually local activities that involve schools and community social stakeholders such as municipalities, non-governmental organisations, associations, etc. It is a project-based approach, where schools address a societal need in their community and develop a project to find a solution or improve the situation.

The development of strong communities of practice around the school-lead projects along with project-based pedagogical methods are the crucial elements for OSOS focusing on science education. In this context, OSOS adopted and adapted the DFC process in guiding schools, teachers and students to develop their projects as follows and as depicted in Fig. 2:

- Feel: Students identify problems or challenges in their local communities. They can also select topics related to global challenges that may affect their communities in the future. Students observe problems and try to engage with those who are affected, discuss their thoughts and ideas of solution in groups, and make a plan of action, based on scientific evidences.
- Imagine: Students envision and develop creative solutions that can be replicated easily, reach the maximum number of people, generate long-lasting change, and make a quick impact. They are coming in contact with external actors, they are looking for data to support their ideas and they are proposing a series of solutions.
- Create: Students are implementing the project and they are interacting with external stakeholders to communicate their findings.

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- Share: Students share their stories with other schools in the community and local media.

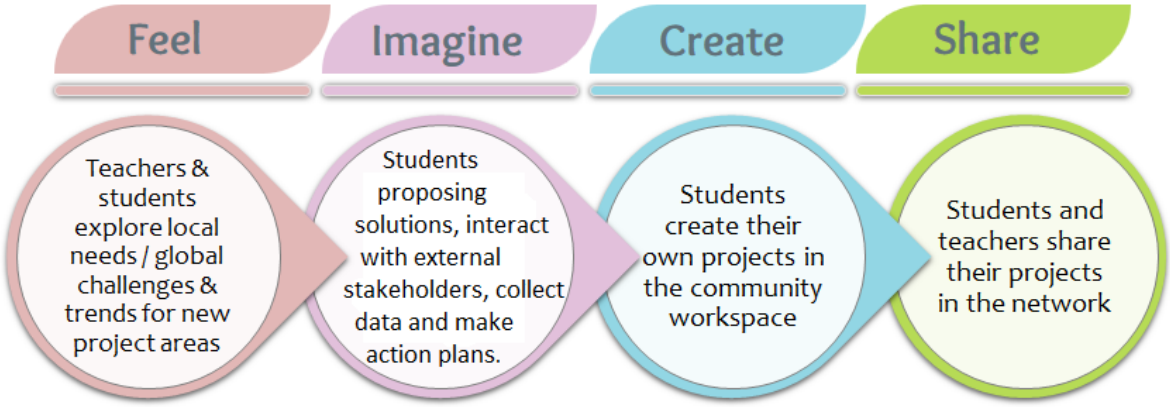

Figure 2 : OSOS authoring platform offers students the opportunity to develop their projects following a simple four-step process based on the DFC model.

OSOS already offers advanced community support and authoring tools for content creation by students and teachers following this four-step process. The aim is to help and enable them to become creators of educational activities which will reflect on the real educational needs of their classrooms as well as they are providing solutions to their local communities. They are able to adopt existing content, enrich it with numerous resources and tools in order to provide integrated solutions to the local problems. SLEs fully embraces a similar approach which can be utilized in developing its educational activities and can be offered in its technical implementation through a proposed platform.

3.3 The Living Labs Practice

In SLEs STEAM approach surrounded by open schooling environment and organizational structure can be further empowered by the concept of Living Lab. This comes in to expand the horizon and avoid a constraining relative school-centric thinking by contemplating it with a methodological practice to easily accommodate other important actors or to bring them at central stage as well.

A general definition of the term Living Lab is as follows: “living lab is a diverse partnership driven by innovation methodology for co-creation acting in an environment for co-creation and user engagement” (Millet et al. 2015). In this way Living Lab may refer to three different dimensions: partnership, methodology and environment. A partnership is established and focused on the collaboration of different actors from diverse sectors. The partnership usually comprises actors from the public and private sectors, e.g., local public authority, schools, enterprises, and the end-users themselves, who may be involved as individuals or through a civil society organisation. These actors should commit to engaging the project in a co-creation process, devoting time and resources, and accepting that the project may also impact their own work. In addition to partnership, a Living Lab can be thoughtfully defined as a methodology to develop innovation through a user-driven process

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of co-creation. This process emphasizes the central role of the user in the Living Lab approach. Instead of being the target of an innovative solution, the users will be its co-creators, so the solution can be driven by their needs, values, priorities and ethical concerns. This approach is a real commitment for all involved as they are required to deeply participate into a project and really contribute to its development. The methodology often emphasizes the idea of development cycles comprising prototyping, testing and redesigning phases, in a way that is related to engineering design processes.

Finally, the Living Lab approach can be defined as an environment, which can be physical or virtual or both, in which partner engagement, collaboration and co-creation take place. Living Lab projects usually emphasize the importance of real-life challenges and environments in order to try and test solutions in real-life conditions and settings.

In conclusion the Living Lab concept and practice focus on user-driven innovation. Its value in education is being gradually explored including informal and non-formal education settings with the aim to broadly engage audiences or users through co-creation with a wide variety of stakeholders. The value of dialogue and interaction between the audience and other stakeholders along with the opportunity for audiences to participate and reclaim a sense of agency and responsibility in the realm of innovation have been outlined. Starting from the perspective of formal education the "Schools as Living Labs" (SALL) initiative is a project within Europe's aim to promote open schooling and collaboration on science education (https://cordis.europa.eu/project/id/871794). The project proposes the living lab methodology as a technique for the development of open schooling activities linked to science learning in schools. SALL chooses to demonstrate the use of this technique through activities prioritizing a focus on the theme of the food system and its links to the Food2030 research and innovation policy of the European Union representing and bringing in dialogue and mutual learning diverse worlds, from schools, universities and research organisations, to science museums and centres, NGOs and business. In SALL the partnership always comprises the school itself and its teachers and students. Thus, the very first steps of a Living Lab project is to involve other actors to consolidate the partnership and ensure that the collaboration will involve new local actors, out of the schools, in line with the open schooling concept.

Overall, the SALL project has adapted the main elements of the Living Lab approach to the school context with the view to ease its uptake by schools and teachers who may be unfamiliar with the innovation terminology and concepts. Doing so, the term Living Lab is defined as the methodology used to support the collaboration among different partners who want to address a concrete issue relevant to all of them. The methodology uses design cycles typically comprising stages of creating rough ideas together after exploring the issue under study, then quickly identifying elements of the solution, which can be built upon as working prototypes and finally testing and evaluating the solution with users and getting feedback to improve them. This cycle can be implemented several times, in an iterative way, to revise the solution at various levels as shown in Fig. 3 (Aguirre 2021).

In this framework the key principles and main steps of development of a Living Lab project are defined as:

- Start from a real issue with a goal to study, develop and propose a real solution, making use of the participants' personal experience. This principle ensures that the project focuses on an issue and not only on a general idea, and that the main driver of the project will be to look for solutions, and furthermore to have those solutions implemented.
- Actively involve all societal actors in co-creation. Those can be local actors, individuals or institutions that have some common direct or indirect interest with the school, and that are benefited or affected by the process or the project's outcomes.

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- Conceptualize, design and propose solutions using all the perspectives that are present in the partnership, thus maximizing the various levels and types of expertise from different actors. The school students would generally be the core team to generate ideas, but those ideas would have to be discussed, shared and built with the other actors.

Aim to put in practice and test early and quickly preliminary solutions with users. By prototyping initial versions of possible solutions, the learning value of a project is coming both from the study of an issue, but also from the transformation of an idea into prototype and the testing with real users.

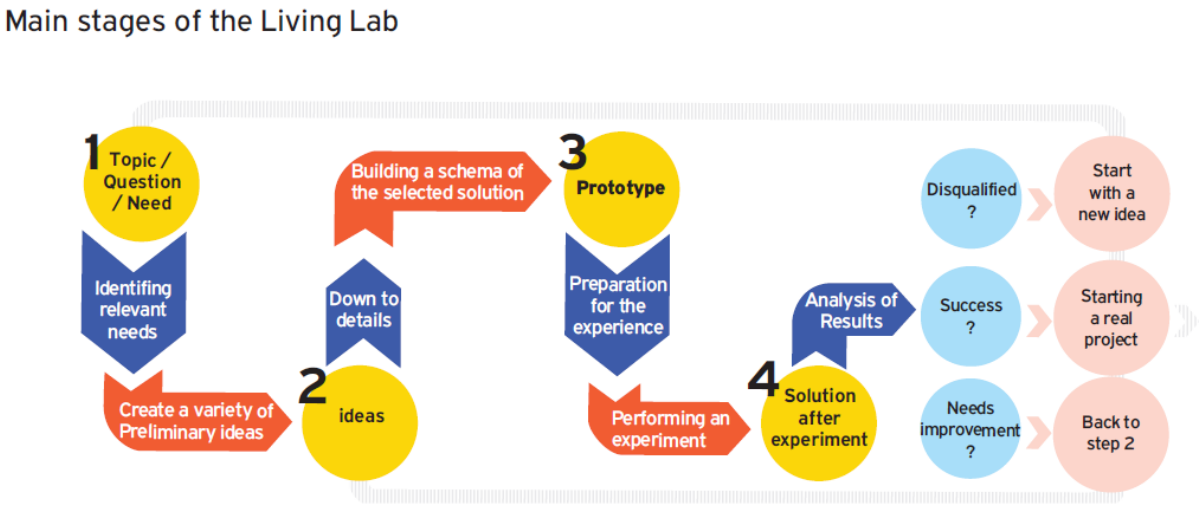

Figure 3 : Main stages of the Living Lab methodology as proposed in SALL project (Aguirre, 2021).

These key principles are fully encompassed in SLEs view of learning activities, and their scope is extended to include issues related to Green Deal, Health and Digitalisation. Adopting the living lab process from conception to solution offers an affluence of learning pathways in constant dialogue and exchange of all actors involved. This characteristic further has the potential to serve SLEs' objectives on facilitating diversity and inclusion in learning as it encourages or helps to address issues that are brought-up or strongly affect under-represented groups with respect to e.g. socioeconomic background or gender.

A living lab approach has been also widely implemented throughout the GenB project ("Informing and educating young people on more sustainable behaviours and choices to build a future generation informed and interested in bioeconomy", https://cordis.europa.eu/project/id/101060501). Learning lessons and good practices deriving from this project can therefore feed the SLEs activities. Within this project, living labs are implemented in schools through formal workshops that follow a four-stage approach (Leminen 2012; Millet et al. 2015):

- Co-creation/co-design: This is the ideation stage. With the help of different co-creation tools and methodologies, the participants develop a portfolio of possible ideas that they could implement to reach their desired goals.
- Exploration: at this stage the participants explore the ideas in more detail and together come into a consensus on which ideas they would like to produce and experiment on. In this stage, they develop prototypes of the ideas or bring them to life so that they can deploy them to the target population in the next stage.

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- Experimentation: At this stage, the participants test the developed prototypes or products with the target population.
- Evaluation: At the final stage, the participants of the living labs reflect on how their product or products were received by the target population, whether they managed to reach the goals they were intended for and whether any adaptation is required.

Concluding, SLEs plans to closely collaborate with SALL and create opportunities for synergies at various levels including those related to implementation of activities, development of methodology, exchange of outcomes and findings. At more technical level it is in SLEs interest in utilizing SALL's platform for content creation by partners, teachers and students following the living lab process.

3.4 Local Partnerships as Learning Ecologies

Successful learning in the 21st century depends upon creating connections and paths across areas of knowledge and subjects as well as to the community and the wider world (Graff 2012). This emphasizes the fact that knowledge and technologies do not exist alone and are not progressing in isolation. Insight, interdisciplinary progress and innovation are primarily about team-work and diverse partnership and collaboration, where different members bring different skills and perspectives which together lead to added benefits (Blackwell 2009).

This is the vision of SLEs practically manifested in fusing STEAM approach, open schooling environment and living lab practice within an empowering partnership based on local-level collaboration between formal, non-formal and informal science education providers, enterprises, and civil society. Such fusion offers a unique opportunity to bridge the gap between formal education and business by developing an appropriate catalysing process in a connected science learning ecosystem where students encounter a wide range of learning experiences and are supported and mentored by experts and peers in ways that could lead to future opportunities in personal, academic, professional, and civic realms enabling new ways of thinking about societal challenges. Essentially this requires both educators and organisations to think and act beyond their own institutions and envisage how collective action at network level can provide opportunities for all. Herein comes naturally the notion of a learning ecosystem with a plurality of possible interventions, powerful interactions and intense pathways over time and across the many contexts where learning may occur (Hannon 2019). SLEs invoke pathways as a metaphor for thinking about ways to provide structure to learning experiences, about how they are inter-connected and inter-related and about how they allow or help learners to build upon them to pursue goals requiring extended engagement across multiple contexts and learning opportunities.

In this framework SLEs put forward the concept of learning ecologies to offer a powerful new way to envision and develop impactful local open schooling partnerships as science learning continuum for all. This conceptualisation implies revisiting open schooling and viewing it more towards enhanced openness not only of the school but of all formal and informal learning spaces in a local context, as well as towards enriched learning opportunities not only for school communities but for all citizens in multiple and interconnected learning spaces including the workplace and the civil society. Thus, emphasis is put on providing formal education students, non-formal and informal learners, such as in NGOs, youth organisations etc., as well as citizens from all walks of life, irrespectively of age or inclinations, with opportunities to create and follow their paths to meaningful learning and engagement within their learning ecologies.

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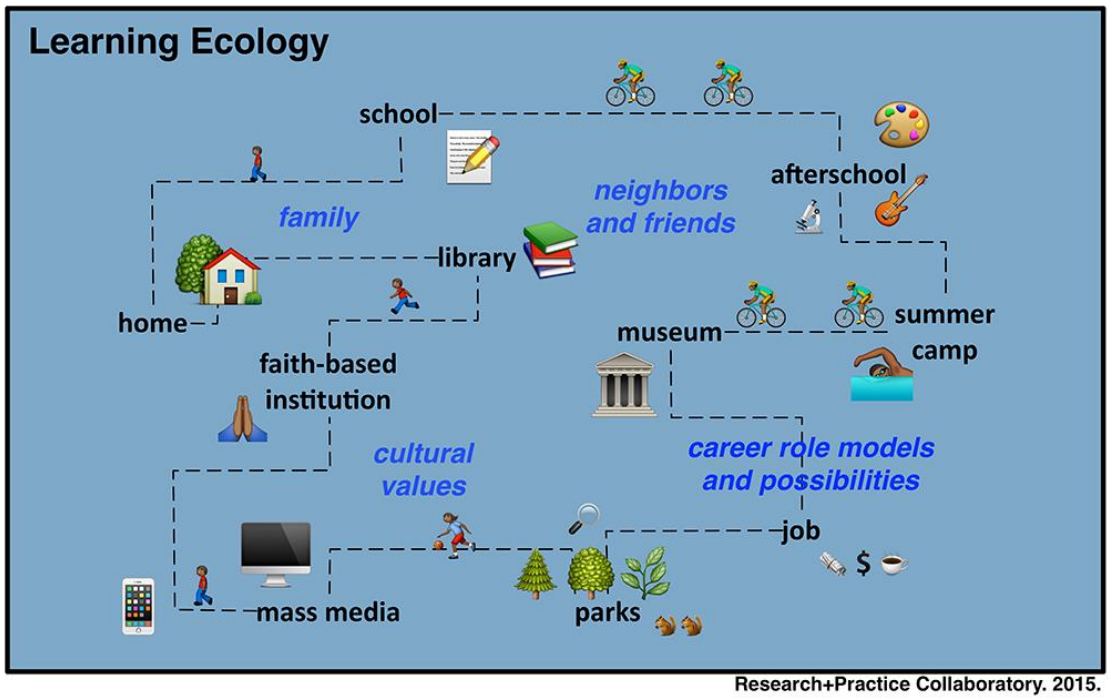

Figure 4 : A graphical representation of the Science Learning Ecology describing the learning paths of individuals in the form of a science learning continuum (Bevan 2015).

Elaborating further on the definition of the concept of learning ecologies, a learning ecology is the physical, social, and cultural context in which learning takes place. Like natural ecosystems, learning ecologies have physical dimensions, which beyond formal education organizations may include easy access to nature, science museums, or advanced science programmes or internships. However, beyond the physical dimension, we have also to think about their sociocultural dimensions. Robust science learning ecologies, like their counterparts in nature, are characterised by diversity, redundancy, and local adaptations. This means that a robust science learning ecology contains a variety of programmes, across institutions and places, allowing people in different and multiple ways to engage with science in the form of a learning continuum (NRC 2000/2018).

For the purposes of the SLEs project we synthesize a generic definition of the term which is the following: a learning ecology is a set of established relationships and interactions between educational stakeholders and its surroundings or environment including civil society and enterprises that can offer, support or cultivate an abundance of learning opportunities for all. In a learning ecology, on the one hand individuals take increasing levels of ownership over their own learning as they grow older and gain more experience, and on the other several collaborative partnerships are forged and networks are created to optimise opportunities across a range of institutions and organisations. Thus, a committed local partnership, resembling a real ecological system in nature, has the potential to initiate and generate in time a rich and robust complex system of relationships, interactions, pathways and opportunities of collaboration and development, which was neither prescribed nor predefined. At this point it should be stressed that the term system may have negative connotations because it is usually associated with top-down approaches or efforts of reform with profound limitations. Contrary to this, in SLEs vision, learning ecosystems have more horizontal or

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bottom-up character and can enable collaboration and stimulate innovation at multiple fronts without constraining control.

In general, ecological theories of learning are based on the idea that learning develops over time and in multiple settings, as shown for example in Fig. 4. Learning opportunities are made possible and shaped by the learning ecology that one inhabits (Bevan 2015; Jackson 2019). Thus, at the heart of an ecological perspective on learning is the need to make connections across formal, informal, and everyday learning. This can be done by creating collaborative partnerships and networks to facilitate, optimize and multiply opportunities of learning across a range of institutions and organizations.

Ecological perspectives on human development and learning were introduced several decades ago and were based on an ecological systems theory of child development (Bronfenbrenner 1979). It offered a framework for understanding human development through the lens of the different environmental systems with which an individual interacts. More recently, similar perspectives have informed research and studies demonstrating how young learners develop interest, capacities, and commitments to a field or discipline across time (Barron 2006) and more importantly that these are context dependent (Azevedo 2011; Bell 2012; Barton 2000; Pritchett, 2013). Thus, ecological perspectives call for more intentional nurturing, mentoring and brokering of learners' interests at the level of organizations or communities spanning across the broader learning ecology. It is one of SLEs objectives to bring forward the essential aspect of mentoring in the learning ecologies to be developed and offered.

Being in a learning ecology requires us to observe, interact and understand what others are doing, not only within our immediate close circle, but also in the broader community, civil society and enterprises, to help us explore opportunities and extend our learning trajectories (Hannon 2017; Mueller 2015). This includes not only learners but also educators who need to be meaningfully connected with one another and across institutional settings, so that they are best positioned to help or encourage learners to navigate around and make their own connections in a learning ecology. In a sense this perspective is not centred on the learner but to all actors involved who are being simultaneously educators and learners as they all need to look around to understand what kinds of opportunities are available and how to build resilience through creating both diversity and redundancy and make intentional connections (Covay 2010). Therefore, in SLEs our goal is to bring in all actors involved within a clear methodological framework of proposed actions so that they are empowered to co-create or build upon and expand learning experiences which are relevant, responsive, and connected with their local communities and beyond (Clarke 2012).

In SLEs vision the concept of learning ecology brings at front stage and materialises the notion of learning continuum. A learning continuum can be considered at multiple levels. At fundamental level is the cognitive continuum, a continuum of cognitive processes, which is invoked in our effort to understand the world (Fig. 5). When we explore and try to understand and solve a challenging problem or encounter a situation that is new to us, we use our perception, imagination and our reasoning in a powerful interplay. This can be represented as a continuum (Fig. 5) in which imagination, and in the broader way creativity, has the potential to connect to both perception and reasoning in a pragmatic and productive way (Pendleton-Jullian 2016; Withagen 2018). The situations we encounter or create provide the context, motivation and inspiration for this productive way of thinking which generates the insights we need to perform and flourish.

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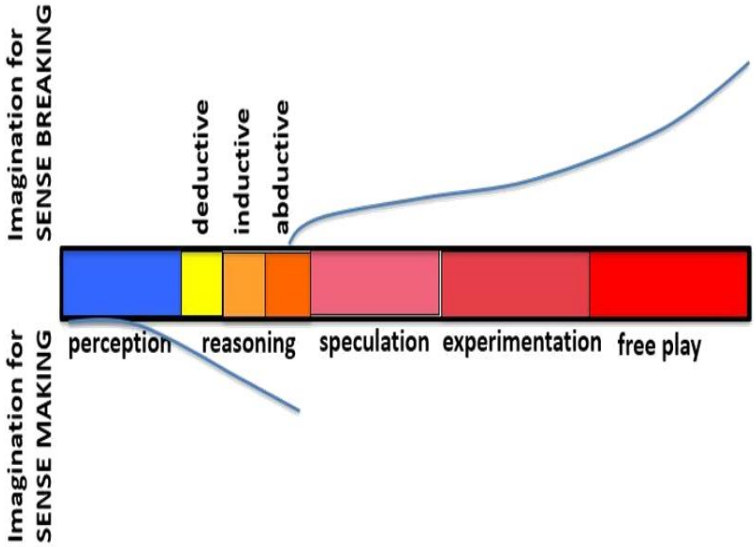

Figure 5 : A continuum of cognitive processes, which is invoked in our effort to understand the world (Pendleton-Jullian 2016).

Inhabiting learning ecologies involve us, partly intentionally and partly unintentionally, in a similar cognitive continuum of processes. By observing and thinking about our own interactions with our physical, technological, social, cultural environment as we work on problems, engage with challenges or develop opportunities, we access and interpret information, perceive patterns, create knowledge and reason to understand relationships and causes and effects in a dynamic, diverse, complex and rapidly changing world.

In reciprocity, when we encounter a new situation, problem, challenge or opportunity, we use our senses, knowledge, prior experiences, beliefs and biases to perceive and comprehend the situation and act in ways that are appropriate or relevant for the context. Effectively, we create and inhabit an ecology that enables us to perceive, comprehend and interact with our environment in order to accomplish the things that matter to us, and learning and achievement emerge from this process. In this way we and our environment are always related. The ecology unifies and embodies our cognition, thinking and acting up on our concerns, with the environment that provides us with the opportunities to learn and act. Furthermore, it is the basic process through which we come to know and understand a situation and the effects of our actions. This paradigm of learning means that we keep on developing as long as we keep interacting with our environment.

An environment is a combination of several components of contexts, partnerships, relationships, places, resources and activities altogether embodied in the features of a learning ecology or associated with it (Jackson 2019). As depicted in Fig. 6, at the core can be an individual or group of actors and all they can bring to a situation interacting with their environment in a purposeful way, which is the motivation to initiate and sustain an ecology. The components of a learning ecology are to be woven together, forming a continuum, by the learner and in a deliberate or opportunistic act of trying to achieve something and learning in the process. They do not stand in isolation, instead they can and do connect, interfere and become incorporated into other learning ecologies. Hence a learning ecology enables the learner to think and act in a connected, relational and integrated way; to perceive, observe, sense and comprehend the flow of information; to imagine, conceptualise and transform what has been observed in order to create possible meanings and new interpretations; to

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reason, analyse and critically evaluate observations and conclude or decide; to reflect on, make better sense of and learn from the whole experience.

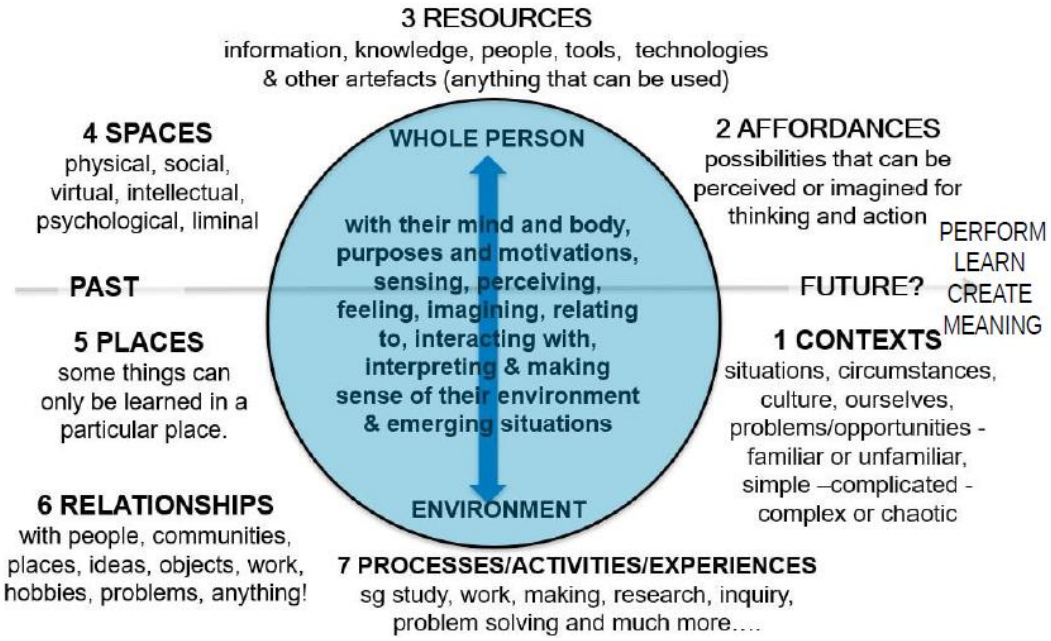

Figure 6 : Components embodied in the features of a learning ecology or associated with it (Jackson 2019).

It should be emphasized that an essential characteristic of a learning ecology in SLEs is the absence of rigid, static, fully predefined and constrained design. A learning ecology is inherently dynamic, flexible and accommodative and has constituent elements which are diverse, interconnected or interrelated, constantly interacting and evolving. It thus not only attracts participants from various backgrounds but also enables all involved and in particular learners to create, explore and incorporate new relationships, activities, resources, contexts, situations and experiences, and gives them freedom or flexibility to modify them through inquiry, analysis and synthesis in ways that they find them more meaningful or relevant, and through which they can be more effective or impactful. In addition, through its richness of possible relationships between people, contexts, ideas and concerns, it gives learners the means to connect and integrate past and present experiences, thoughts, actions and imagined future outcomes, and organise them into novel thinking and action through which new patterns of understanding can emerge. Lastly, it enables and connects learning and practice beyond a particular environment, context and situation.

In SLEs perspective, the key to creating a vibrant and thriving learning ecology is to work across all levels of the learning ecosystem, with educators, organizations, and policy makers, and to start by establishing local partnerships as the driving force of learning ecologies in which everybody contributes and benefits. And in which all participants share a common intention of embracing the complexity that surrounds an individual's experience of learning and development in the various systems and environments (Pritchett 2013). This emphasizes the value of meaningful co-participation and co-creation of activities, mutual respect and responsiveness from the entire environment. It suggests that both young students and lifelong learners are capable of being relatively independent and self-directed when they are given freedom and sufficient opportunities to

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participate meaningfully in authentic activities across the learning continuum (Baker 1999). This also entails educators in all types of settings within a learning ecology recognizing young learners' interests, skills, and personal areas of expertise, building on what they bring to the learning experience, supporting them in integrating these into their learning and helping them find a way to deepen them, explore and see how these can extend into the future by following relevant studies and careers. It crucially involves building on one's prior knowledge or making seamless connections between e.g. the science curriculum and science in the broader world, across time and settings throughout the day and across the lifespan (Hannon 2017).

It is worth noting that the concept of learning ecology can be seen as the application of the ecosystem metaphor to education and learning both as an analytical tool and as a practical strategy (Mars 2012; Maroulis 2010; Levin 1998). In this respect when designing learning ecologies it should be taken into account that natural ecosystems both provide and require:

- diversity by accommodating and actively involve multiple actors that fulfil many roles;
- efficiency by optimally sharing, distributing and recycling resources which include knowledge, experience and expertise;
- adaptability by responding to learner needs and changes of circumstances or environments;
- scalability by operating or by having the ability to be implemented on various scales, from small learner groups or specific schools to a whole community of practice.

It is of SLEs aims all such essential features to be the main cornerstones of the learning ecologies that the project will develop.

Synthesizing on all discussed and highlighted above in this section, but also in previous ones, we conclude that by fusing STEAM approach, open schooling environment and living lab practice, what we call STEAM Learning Ecology, we offer and cultivate directly or indirectly the development of numerous opportunities, access points and pathways for engagement of multiple actors, and in particular for learner meaningful engagement. If this is combined with vibrant mentoring schemes to encourage or guide learners to follow related studies and careers, then this further and naturally influences their future choices or helps to increase inclusion and diversity in STEM fields. Although learner future choices are one of the main objectives of recent and past actions and initiatives, mentoring is rarely addressed or sustained. And in cases where it is addressed it is only considered in one direction, from research or enterprise to education, and usually not from research to enterprise in order to facilitate innovation transfer. The in-context development of numerous opportunities, access points and pathways of all involved and their thriving is the so-called network effect. The cornerstone to initiate a network effect and capitalise on its impact is a committed partnership of diverse actors with a purpose of cross-collaboration, co-creation and sharing. A vivid and dynamic partnership in the form of a STEAM Learning Ecology cannot be just instantiated and then flourish on its own without having a concrete methodological structure to guide its built-up and drive its initial phases. Therefore, taking into account what we presented both from abstract and practical perspectives in this section, we postulate six key dimensions on which SLEs methodological framework will be based and along which STEAM Learning Ecologies will be designed and developed accordingly. These are as follows:

- Partnerships to foster networking, sharing and applying science and technology research findings amongst stakeholders.
- Mentoring for everyone in the partnership to take full advantage of science, technology, research and innovation.
- Learner Meaningful Engagement to provide improved science learning opportunities in formal, non-formal and informal education spaces and in the workplace.

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- Learner Future Choice to encourage learners to follow STEM studies and careers, and to increase inclusion and diversity in them.
- From Research to Enterprise to increase the application of science and innovation research results to business.
- From Enterprise to Learning to link industry-based practice, insight and innovation with lifelong learning programmes.

These dimensions form a concrete structure on which SLEs is founded to bridge concept and methodology, as shown in Fig. 7 below. Many, if not all, of these dimensions have been already addressed in other initiatives, however to our knowledge they altogether were not explored simultaneously or at equal level (e.g. see Table 1 of section 2.3). To this end Fig. 8 depicts in which respective area work in other initiatives can be re-utilised in or support SLEs methodological structure.

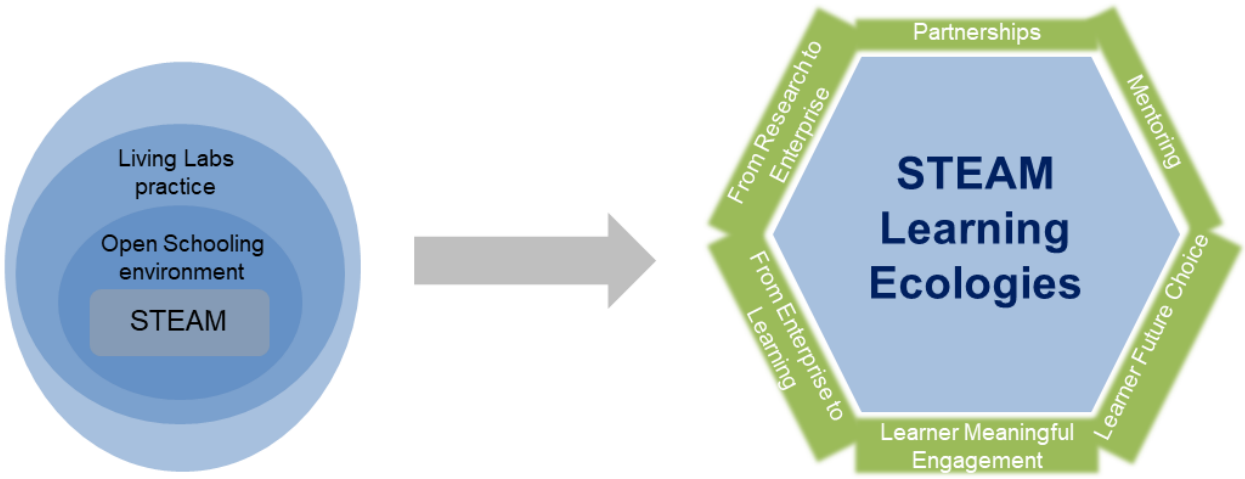

Figure 7 : From abstract conceptual constructs to practical key dimensions of methodological structure.

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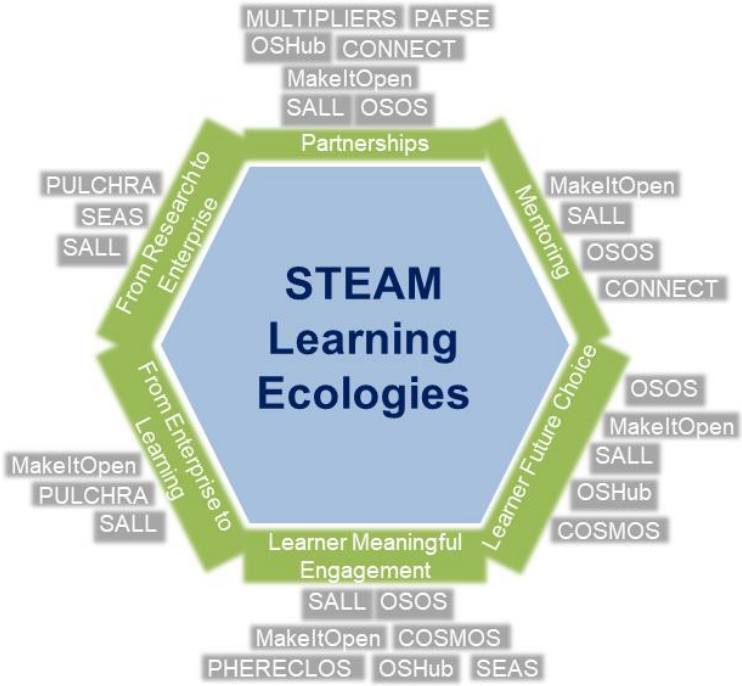

Figure 8 : SLEs' methodological structure in relation to other initiatives.

Summary and Future Steps

The SLEs White Paper is the first deliverable of Work Package 2. In this document we have laid out the main foundational elements on which the SLEs approach and vision are based. We started by describing first the driving needs and aspirations, the policy context, and the relevant initiatives, and then continued with the constituent elements of the SLEs perspective. These include STEAM as the overarching approach, the open schooling as the main pillar and the living labs concept as key practice, altogether synthesized into local partnerships as learning ecologies. We discussed in detail each of these four aspects highlighting their key principles and characteristics.

In summary, in SLEs we envision and embrace STEAM education as an overarching approach across STEM subjects, the arts and all other disciplines that can greatly infuse and increase interdisciplinarity, creativity, problem-solving, critical thinking, integration and inclusiveness in school education and life-long learning. Using STEAM in education is about using subject integration coherently as an instructional approach for experiential and inquiry-based learning that provides multiple access points and diverse learning pathways for all learners to engage in the creative process and meet objectives in all subject areas. We believe that this manifold of access points and pathways is in its nature inclusive as it gives space for all to explore, freedom to follow unchartered regions and confidence to think differently or be different.

We appraise and leverage this approach by embedding it in open schooling environment through living labs practice. This choice is a key opportunity enabler and multiplier by inherently offering a wide spectrum of access points for all involved. To this end our plan in SLEs is to closely collaborate with SALL and create opportunities for synergies at various levels including those related to

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implementation of activities, development of methodology, exchange of outcomes and findings. At more technical level it is in our interest in utilizing SALL's platform for content creation by partners, teachers and students following the open schooling living lab process.

Our overall vision in SLEs is to fuse STEAM, open schooling environments and living lab practices within an empowering partnership based on local-level collaboration between formal, non-formal and informal science education providers, enterprises, and civil society. Because such fusion offers a unique opportunity to bridge the gap between formal education and business by developing an appropriate catalysing process in a connected science learning ecosystem where students encounter a wide range of learning experiences and are supported and mentored by experts and peers in ways that could lead to future opportunities in personal, academic, professional, and civic realms enabling new ways of thinking about societal challenges.

Along this line we put forward the concept of learning ecologies to offer a powerful new way to envision and develop impactful local open schooling partnerships as science learning continuum for all. We invoke pathways as a metaphor for thinking about ways to provide structure to learning experiences, about how they are inter-connected and inter-related and about how they allow or help learners to build upon them to pursue goals requiring extended engagement across multiple contexts and learning opportunities. In our view of a committed local partnership we want it to resemble a real ecological system in nature, which has the potential to initiate and generate in time a rich and robust complex system of relationships, interactions, pathways and opportunities of collaboration and development, which was neither prescribed nor predefined. In this respect when designing learning ecologies we should take into account that natural ecosystems both provide and require diversity, efficiency, adaptability and scalability. And so, we should ensure that these features are present in our methodological approach. Regarding our methodology we postulate six key dimensions on which our methodological framework will be based and along which STEAM Learning Ecologies will be designed and developed accordingly, these dimensions are partnerships, mentoring, learner meaningful engagement, learner future choice, from research to enterprise, from enterprise to learning.

Concluding, in SLEs our next goal is to bring in all actors involved within a clear methodological framework of guidelines and proposed actions, so that they feel empowered to co-create or build upon and expand learning experiences which are relevant, responsive, and connected with their local communities and beyond. These actions will be based on the foundational concepts laid out in this White Paper. In doing so, our next step is to work towards developing a concrete methodological framework which will be documented in the second deliverable of Work Package 2.

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