Project Result 1

SEISMO-Lab Framework for Establishing STEAM School Competence Labs

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Abstract	This document presents the SEISMO-Lab Conceptual Framework that defines the educational criteria for the competence labs and their proposed pedagogical activities. It offers guidelines in the form of detailed educational templates for schools and teachers allowing them to organise, establish, and ultimately implement a STEAM-based approach using student-centred educational activities in seismology, and within the broader domain of earth sciences. This framework will outline and explain the principles of STEAM teaching through participatory, inclusive, cross-curricular learning challenges that will include innovative and effective pedagogies such as inquiry-based learning, project-based learning, and learning cycle. This will engage students in projects designed to enhance their problem-solving skills and creativity and will also promote a learning-by-doing attitude. The SEISMO-Lab Framework offers concrete guidelines on how to develop school-based curricula and how to implement and integrate the STEAM education approach into the school setting. It will provide examples and ideas on how seismology, scientific data, and student-centered projects, with the collaboration and cooperation of external stakeholders, may lead to the development of innovative solutions, products, and projects that can benefit the whole school community. This approach reinforces the development and application of key skills and competences (beyond scientific ones), which are adapted to local conditions, by means of employing problem-solving skills, handling and studying situations, and participating in meaningful and motivating science inquiry activities around the topic of earthquakes and their impact on society. The SEISMO-Lab Framework is an essential tool that helps schools to establish and operate open science labs for students and teachers, while also offering an opportunity to all stakeholders in the (school) community to participate actively in the proposed activities. It is based also on the principles of Open Schooling that offers concrete steps for creating the necessary school environment to establish labs in each participating school and provide guidelines for facilitating cooperation with external stakeholders. Consequently, schools are engaging students in real-life projects that need to find and design innovative solutions by employing problem-solving skills, while they ate dealing with real scientific data that students have acquired themselves. Even more, the SEISMO-Lab Framework will also apply a state-of-the-art approach in the introduction of Responsible Research and Innovation (RRI) in school settings. It will offer an outline of how any SEISMO-Lab school can embark on the process of project-based teaching and learning while adhering to the use of RRI-enriched activities. Participating schools will benefit greatly because it: - Provides unique PD experiences for school staff to create their inter-disciplinary school STEAM curriculum. - Enables schools to connect with local stakeholders, science centres, and community

	members. - Expands participants' horizons by enabling them to work with partner schools on scientific activities, developing new seismometers and conduct experiments with other schools of the network. - Improves teaching and learning through interdisciplinary project-based learning while assessing and providing valuable feedback on student performance. - Raises the profile of each school that becomes part of the network, encouraging them an active part in international activities.
Author(s)	Dr. Sofoklis Sotiriou and Dr. Gerasimos Chouliaras
Contributor(s)	Konstantinos Boukouras, Thodoris Karafyllidis, Stavros Eleftheriou, Yvoni Pavlou, Marios Papaevripidou, Dragos Tataru, Eduard NastaseBogdan Zaharia, Adina Vanciu-Rau, Bulent Cavas. Aylin Gil. Bircan Gisi, Seden Kırte, Luigi Cerri, Livia Capocasale, Rossella Parente
Reviewer(s)	Thalia Tsaknia
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Executive summary

Seismology in school education promotes scientific literacy at all levels but its benefits go far wider than providing scientific knowledge. The subject of earthquakes introduces geography and Earth science concepts and related content while promoting key competencies aimed at the intellectual (i.e. science understanding and knowledge, scientific reasoning, computational thinking and skills, geospatial understanding, etc.) and motivational abilities (collaborative problem solving, creativity, critical thinking, communication, etc.) that are reinforcing students' interest and fascination in science and that together form the **Deeper Learning Framework of Competences** (Deeper Learning Paradigm - William and Flora Hewlett Foundation 2013). SEISMO-Lab supports the creation of Competence Development Labs, developed and run by teachers that will then be able to create "bottom-up" STEAM curricula for their schools, thus enabling students to practice competencies and skills that go beyond STEM. Students take on the important part as researchers and this project promotes their active participation. The objectives of the SEISMO-Lab are to: a) Support the reform effort to create bottom-up innovative STEAM curricula that focus on the development of key competencies, b) create a set of related scenarios, the SEISMO-Lab Demonstrators that support students in developing their problem-solving skills, creativity, and promote a learning-by-doing attitude in meaningful and motivating inquiry activities on seismology education, c) help teachers to set-up STEAM activities in which students learn, practice and utilize scientific instruments and methods while they have to communicate the outcomes of their work and d) expand the network of school seismometers in different EU countries.

This Project Result (PR) describes the design of the **SEISMO-Lab Framework for Establishing STEAM School Competence Labs**, highlighting the key features and the key parameters for the design of such interventions that require effective curriculum adoptions and significant organizational changes. In this way, this work will form the basis for the design of the SEISMO-Lab Demonstrators (PR2) and the development of the SEISMO-Lab online platform and space for teachers (PR3). Cooperation with the research (NOA and NIEP) and museum (IDIS) partners was very important for the finalization of the proposed methodology. Two tasks supported the production of this PR:

Open Schooling Model and Strategies. The task includes a literature review in the field of open schooling and describes the current situation that teachers and students must deal with. The Open Schooling approach promotes the adoption of innovative educational practices, which blend the advantages of formal and informal science learning, within school communities. This approach recognizes the crucial role that external stakeholders can play in the schools development. The SEISMO-Lab online platform, designed for educators, serves as an open and interoperable web environment that emulates the collaborative work of the scientific community within school settings. Using this platform as a starting point, the project team will assist schools in crafting their unique educational pathways for the effective integration of seismology into the school curriculum. This work is presented in Chapters 1, 2, 3, and 4.

Definition of Implementation Parameters for the Integration of the STEAM Competence Labs. This task describes the pedagogical framework - including all the necessary parameters for the introduction of the project to school settings. It provided detailed descriptions of the approach to support project partners in designing the SEISMO-Lab educational scenarios (the SEISMO-Lab Demonstrators) and to offer opportunities to the educational community

to design their own educational interventions as part of operating STEAM Competence Labs. The definition of the implementation parameters along with the pedagogical design demonstrates an innovative learning scheme that not only crosscuts the boundaries between formal and informal learning settings, but also recognizes the diversity of personal learning styles.

The SEISMO-Lab Framework is the result of an extended interaction between existing knowledge in the fields covered (formal and informal science learning, inquiry-based learning and resource-based learning), and the concepts and objectives of the SEISMO-Lab project. The aim of this interaction was to identify the state-of-the-art and explore and promote significant opportunities for innovation enabli effective exploitation of the rich educational content available in the scientific databases and archives of seismological research.

Important tools in the process of consortium-wide consultation are the 'SEISMO-Lab Demonstrators Templates'. These templates are presented in Chapter 6. Partners were invited to participate in a structured exchange of views about the integration of Competence Labs in the school curriculum. The outcomes presented in this chapter of the PR have been informed with all input and feedback received from the project partners through these consultation procedures.

The preparation of this document was the last step in the process, aiming to present and explain the rationale, background and details of the SEISMO-Lab Framework and thus provide input to the next project phases. More specifically this PR consists of the following chapters (after a short introductory chapter which introduces the project's key aspects and the purpose of this document).

Chapter 2 describes the SEISMO-Lab Framework. It describes the pedagogical principles for the design of the SEISMO-Lab Demonstrators and the expected learning outcomes for students. It presents their key features and the context of their implementation. The chapter concludes with the presentation of the project team's vision of designing Competence Labs that are acting as hubs of innovation in the school community. The chapter highlights that the current organisation of the ERASMUS+ programme for schools' cooperation and exchanges offers unique opportunities for the introduction of such interventions at an international level. This is an example of continuous learning scheme that includes seeking out better resources and learning from one's own experiences and from the experiences of others.

Chapter 3 presents the guiding principles and the conditions that must be in place for the SEISMO-Lab Framework to be implemented. It focuses on how teachers can empower students as learners; how to contextualise knowledge so it is coherent; how to connect learning to real issues and settings; how to extend learning beyond school walls using the unique resources from informal learning settings; and how to inspire students by customising learning experiences. It also focuses on how the use technology could be in service of learning. The chapter highlights the key conditions that school heads must have in mind if they want to embark their schools in the transformation journey: to establish a learning culture in the school environment; to create shared responsibility for students' learning; to establish a culture of trust and professionalism; and to preserve time for teachers to collaborate.

Chapter 4 defines in practical terms for the sake of the consortium, the school heads and the individual teachers, the tailored strategies to support local schools as they transform themselves into open schooling environments while they are implementing the SEISMO-Lab Framework.

Chapter 5 presents the key offers of the SEISMO-Lab project, namely the access to unique resources and educational scenarios, the opportunities to design unique STEAM activities in the framework of contextualized experiences and the guidelines for the design of inclusive experiences for all students, based on the Universal Design for Learning model.

Chapter 6 could act as the integrated guidebook for the design of the SEISMO-Lab Demonstrators as it presents a) the SEISMO-Lab environment as a Deeper Learning Classroom and b) the detailed structure of the proposed educational scenarios templates for the most effective instructional models. The design template of the SEISMO-Lab Demonstrators integrates the key features of the project's approach; it is based on the different effective science education instructional methodologies that have been adopted to support the operation of the SEISMO-Lab Competence Labs in the participating schools.

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1 Introduction

1.1 Background

Some young individuals readily engage with their school studies, while others struggle to discern the 'relevance' of their coursework. However, few things are as empowering as the act of devising solutions to real-world problems. When students delve into local and global issues and then endeavour to propose viable resolutions, they cultivate independence in their thought processes. Authentic problems present substantial learning opportunities, as students are compelled to embark on research, formulate hypotheses, create, test, analyze, revise, and synthesize their findings.

By functioning as Competence Development Labs, schools can extend to students the chance to actively participate in decision-making informed by science and knowledge-based innovation. The field of Seismology within schools represents an underutilized avenue for harnessing a student's inherent curiosity regarding natural phenomena in their surroundings. This curiosity can serve as a foundational platform for imparting a diverse array of cross-curricular key competencies, skills, and fundamental principles. Our comprehension of the impact of earthquakes on societies begins with the knowledge we glean from the study of seismology.

Incorporating seismology into the educational framework not only enhances scientific literacy across all levels but also extends its benefits beyond the mere acquisition of scientific knowledge. The subject of earthquakes introduces fundamental Earth science concepts while fostering skills and competencies geared towards intellectual development (e.g., scientific comprehension and knowledge, scientific reasoning, computational thinking, geospatial understanding, etc.) and motivational capabilities (such as collaborative problem-solving, creativity, critical thinking, and effective communication). These elements collectively contribute to the Deeper Learning Framework of Competences, stoking students' interest and fascination in the realm of science. (Deeper Learning Paradigm - William and Flora Hewlett Foundation 2013)[1].

SEISMO-Lab supports the creation of Competence Development Labs, developed and run by teachers that will then be able to create “bottom-up” STEAM curricula for their schools, that are enabling students to practice competences and skills that go beyond STEM: learner independence – and interdependence – through collaboration, mentoring, and through providing opportunities for learners to understand and interrogate their place in the world. Students take on the important part as peer enquirers/researchers and this project promotes their active involvement. The objectives of the SEISMO-Lab are to: a) Support the reform effort to create bottom-up innovative and cross-curricular STEAM curricula that include modern student-centred pedagogies and competence-based learning. b) Create a set of participatory, inclusive, cross-curricular STEAM-based scenarios that support students in increasing their problem-solving skills, creativity, and promote a learning-by-doing attitude. c) Reinforce key skills and competences in meaningful and motivating inquiry activities on seismic risk mitigation. d) Create a training program on pedagogical STEAM practices that are most effective in science education and to e) help teachers to set-up STEAM activities in

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[1] The Hewlett Foundation. “Deeper Learning Competencies.” April 2013. http://www.hewlett.org/uploads/documents/Deeper_Learning_Defined__April_2013.pdf

which students learn, practice and utilise scientific instruments and methods while they have to communicate the outcomes of their work.
The project approach is firmly rooted in the Open Schooling concept (EU 2016)[2], which advocates for collaboration between educational institutions and non-formal and informal education providers, businesses, and civil society. It seeks to enrich these collaborations to ensure the meaningful engagement of all societal stakeholders with science. The goal is to boost interest in science studies, foster science-based careers, enhance employability, and strengthen competitiveness. In this initiative, individual schools are partnering with science centers, museums, industries, research institutes, and universities in an innovative and cooperative endeavour aimed at introducing open schooling methodologies. This is achieved through a grassroots approach, wherein the best practices are harnessed to propel us beyond the confines of existing school structures and towards a shared vision of educational excellence.

Such an innovation program holds significant promise. To cultivate a robust, inventive, and open culture within schools that can independently endure, we must empower educators who are attuned to systemic dynamics to lead the way. This approach avoids the creation of isolated pockets of experimentation that, while interesting, may not lead to broader systemic change. Such a collaborative partnership nurtures expertise, facilitates networking, encourages knowledge sharing, and applies scientific and technological research findings within the classroom. Consequently, it brings authentic real-world projects to the educational environment, thereby fostering the development of 21st-century competencies, including creative problem-solving, learning through practical experience, experiential learning, critical thinking, and creativity. These projects and activities emulate the dynamics of genuine scientific work, enriching the educational experience.

1.2 Purpose of this document

This Project Result describes a) a cooperation model between schools and informal learning settings (research and science centres), which emboldens the building of the digital education readiness of the educational community, and b) a practical framework to bring this new cooperation model into action. It will describe the process and the institutional reform plan needed for such a cooperation scheme. It has been developed considering the strengths of both formal and informal science pedagogy and will propose a hybrid approach that keeps this cooperation running even when the physical presence of students in such spaces is restricted or limited. The SEISMO-Lab Framework introduces the essential strategies for the development of an innovative learning approach of blended education, which will deliver high-quality educational experiences.

This approach involves the creation of instructional models for innovative educational practices while simultaneously supporting educators in leveraging their digital competencies to implement the proposed educational activities. The project also considers the existing training needs of the target communities, encompassing teachers and students, specifically in terms of competencies related to designing educational activities and employing scientific databases. Furthermore, it involves the analysis of real data. The initiative also investigates strategies that enable science educators, particularly secondary school teachers, to identify activities adaptable to the described model. This equips them with the requisite skills to

[2] http://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.p

address challenges swiftly and ensure that no students are left behind. To facilitate their efforts and maximize their impact, this project will explore how to align the proposed educational activities with the curriculum and propose specific templates to ensure this alignment.

Significant attention is dedicated to identifying the key impediments faced by certain student groups during the COVID-19 era, which hinder them from effectively organizing and proactively participating in their education, thus affecting their inclusion. The role of families is also considered, as they serve as a support system for students engaged in remote learning. The project acknowledges that the lack of scientific knowledge among some parents and their inability to support their children can lead to detrimental outcomes. Additionally, the project explores the potential of adopting specifications, based on Universal Design for Learning (UDL), to cater to the needs of students and teachers with disabilities, ensuring that the project provides equal opportunities for the educational community facing such unforeseen challenges. To achieve this, the proposed methodology integrates the principles of inclusion into the educational design process. UDL plays a pivotal role in this endeavour by offering a framework for creating curricula and activities that meet the needs of all students from the outset. It offers multiple means of representation, options for various forms of expression and engagement, ensuring accessibility for all. Universal design becomes an integral part of core digital literacy skills that students develop as they interact with the SEISMO-Lab Demonstrators and online tools.

2 SEISMO-Lab Framework and Learning Pathways is Seismology Education

Formal schooling is one way of people learning about science. It is organised and guided by formal curricula with a focus on the acquisition of domain knowledge and scientific skills leading to a formal accreditation such as a diploma or certificate.

While extant research[3, 4], provides evidence that people do establish cognitive links between disparate learning contexts and amalgamate the knowledge they acquire, the process of integration displays considerable variability among individuals. The ability to transfer and unify knowledge learned in distinct settings can be influenced by an array of factors, including personal learning styles and strategies, metacognitive awareness, cultural and social determinants, pedagogical approaches, and the intrinsic influence of curiosity and enthusiasm for a particular subject matter. It must be noted thought that the literature demonstrates missing links between formal and informal learning contexts event in similar thematic areas[5, 6]. As out-of-school learning experiences become more common in people's lives (considering the increased number of informal science learning initiatives available), it is crucial to inquire about and better understand how science learning outside the classroom influences them. Such an inquiry process could start by providing valid and systematically evaluated answers to a series of questions such as:

Why are out-of-school learning activities so motivating? Do they also lead to more positive attitudes towards science? To what extent, if any, do they influence people's knowledge and skills? And if not, can these activities be adapted in such a way that they do? How do they relate to formal schooling and how might activities from both contexts complement or strengthen each other? And can informal science learning activities be used to support people in acquiring a scientific way of thinking, so that they can understand and correctly use all scientific information to which they are exposed? Could out-of-school activities support the open schooling strategy of the EU, where schools in cooperation with external stakeholders share the responsibility for student learning?

On the one hand, the vision of the school opening[7] (EU, 2016)[8] is to develop innovative partnerships with external stakeholders that promote student learning. Arguably, these activities may enhance students' motivation and interest in the subject. On the other hand it is questionable whether out-of-school places of learning are really integrated in such educational policy strategies, as there are no standardised processes in place to assess their potential impact on student learning.

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[3] Eshach, H. 2007. Bridging In-school and Out-of-school Learning: Formal, Non-Formal, and Informal Education. Journal of Science Education and Technology 16, 171–190.
[4] Fallik, O., Rosenfeld, S. and Eylon, B. (2013). School and Out-of-School Science: A Model for Bridging the Gap. Studies in Science Education, 49:1, 69-91.
[5] Kim, M. & Dopico, E. (2016). Science education through informal education. Cultural Studies of Science Education, 11, 439-445.
[6] Leonard, S. N., Fitzgerald, R. N., Kohlhagen, S., & Johnson, M. W. (2017). Design principles as a bridge between contexts: From innovation in the science museum to transformation in formal education. EDeR. Educational Design Research, 1(1). https://doi.org/10.15460/eder.1.1.1059
[7] https://www.openschools.eu/
[8] Hazelkorn, Ellen & Ryan, Charly & Beernaert, Yves & Constantinou, Costas & Deca, Ligia & Grangeat, Michel & Karikorpi, Mervi & Lazoudis, Angelos & Pintó, Roser & Welzel-Breuer, Manuela. (2015). Science Education for Responsible Citizenship. 10.2777/12626.

These advancements in science education occurring outside of traditional schooling, as well as within formal education, present a distinctive opportunity to bridge the gap between these two domains. This can be achieved by establishing an effective catalyst: **a cohesive science education ecosystem**. Within this ecosystem, young learners can engage in a diverse range of educational experiences and receive support from both adults and peers. This collective effort holds the potential to lead to future opportunities across personal, academic, professional, and civic domains. This vision necessitates a shift in thinking among educators and organizations, encouraging them to look beyond their individual institutions. They should consider how collaborative actions within networks can offer opportunities and address disparities in a manner that isolated efforts cannot. In discussions about how young individuals can thrive in such an ecosystem, and the interventions needed to facilitate this, the concept of "pathways" emerges as a valuable metaphor. Pathways encourage us to examine the continuous learning experiences of young individuals over time and across various contexts, including home, school, community organizations, science centers, museums, and online platforms.

While there are various ways to conceptualize these pathways, we employ them as a metaphor to structure young learners' experiences, referred to as "**Learning Pathways**" These pathways can be combined or integrated, allowing young people to pursue goals that demand sustained engagement and persistence across multiple learning contexts and opportunities. The forms of these learning pathways are diverse, shaped by ongoing research and discoveries, shifts in societal needs and interests, and changes in personal interests and opportunities. Some individuals describe their learning pathways as a clear, upward trajectory, leading to a defined goal. Others portray their pathways as more irregular, resembling a series of steps or, more commonly, an erratic, uneven line. The opportunities for learning are made feasible by the learning environment in which an individual is situated.

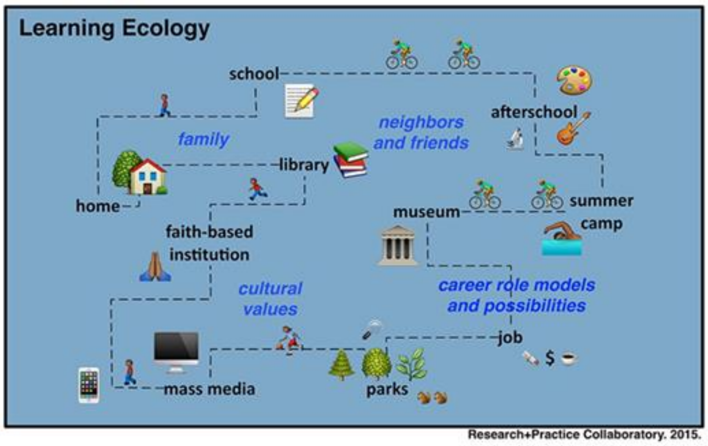

Figure 2.1: *A graphical representation of the Learning Ecology*[9] *that describes the learning pathways of individuals in the framework of school and out-of-school science learning activities.*

A **Learning Ecology** (as illustrated in Figure 2.1 and 2.2) encompasses the physical, social, and cultural milieu within which the process of learning unfolds. Like the dynamics observed in natural ecosystems, Learning Ecologies possess physical attributes that may or may not include ready access to natural environments, science museums, or advanced scientific programs and internships. However, we often underemphasize the consideration of the socio-cultural dimensions inherent to Learning Ecologies.

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9 https://www.nsta.org/connected-science-learning/connected-science-learning-march-2016/stem-learning-ecologies

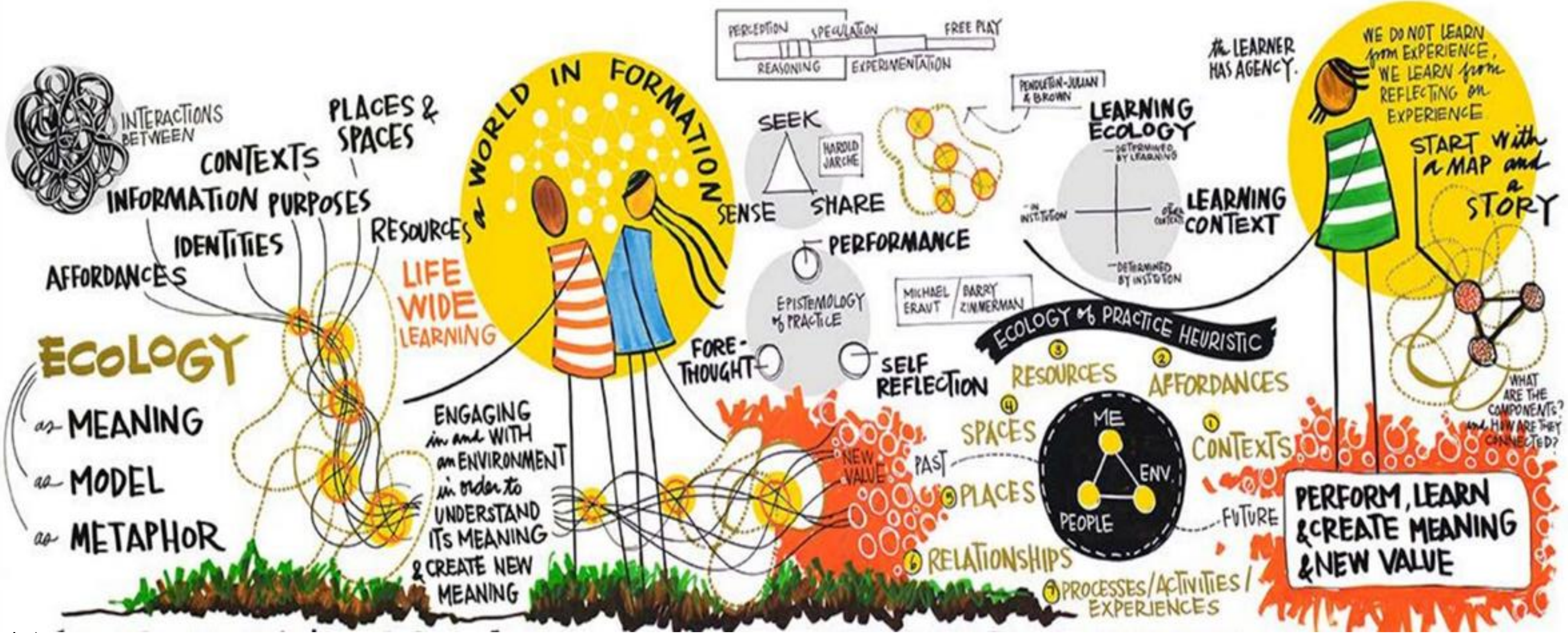


Figure 2.2: *Robust science learning ecologies, akin to natural ecosystems, exhibit characteristics such as diversity, redundancy, and local adaptations. This implies that a robust science learning ecology encompasses a wide array of programs, spanning various institutions and locations, offering young individuals multiple avenues for engaging with science. Learning ecologies are composed of the physical spaces, concepts, institutions, and individuals that are accessible to support the learning and engagement process. The structure of a local STEM learning ecosystem significantly influences the accessibility and quality of STEM learning opportunities. Within this framework, individuals progressively assume greater responsibility for their own learning as they mature and accumulate experience. Numerous collaborative partnerships and networks have emerged with the aim of optimizing opportunities across a spectrum of institutions and organizations.*

These dimensions represent the contextual facets—comprising physical settings, social dynamics, value systems, and historical backgrounds—within which individuals engage in learning experiences throughout their daily lives and over the course of their lifespans.

2.1 Pedagogical Principles in the Design of the SEISMO-Lab Demonstrators

The SEISMO-Lab Framework aims to explore the idea of Learning Ecologies by developing the SEISMO-Lab Demonstrators by providing access to unique seismological data. It aims to propose a generic framework for the design, development, implementation and evaluation (both short- and long-term) of Educational and Outreach activities[10] that can be used to introduce the scientific developments and discoveries across the human history, the nature of science and the principles of Responsible Research and Innovation in science classrooms.

Table 2.1: *The main Pedagogic Principles and the Educational Objectives for the design and implementation of the SEISMO-Lab Framework.*

Pedagogic Principles	Educational Objectives
Sparking Interest and Excitement	*Experiencing excitement, interest, and motivation to learn about phenomena in the natural and physical world.*
Understanding Scientific Content and Knowledge	*Generating, understanding, remembering, and using concepts, explanations, arguments, models, and facts related to science.*
Engaging in Scientific Reasoning	*Manipulating, testing, exploring, predicting, questioning, observing, analysing, and making sense of the natural and physical world.*
Reflecting on Science	*Reflecting on science as a way of knowing, including the processes, concepts, and institutions of science. It also involves reflection on the learner's own process of understanding natural phenomena and the scientific explanations for them.*
Using the Tools and Language of Science	*Participation in scientific activities and learning practices with others, using scientific language and tools.*
Identifying with the Scientific Enterprise	*Coming to think of oneself as a science learner and developing an identity as someone who knows about, uses, and sometimes contributes to science.*

The aim of the consortium is to formulate a set of Demonstrators on how scientific work can be used to provide an engaging educational experience through the exploration of "real science". Research on learning science makes clear that it involves development of a broad array of interests, attitudes, knowledge, and competencies. Clearly, learning "just the facts" or learning how to design simple experiments is not sufficient. To capture the multifaceted nature of science learning, the SEISMO-Lab Framework proposes a roadmap that includes a series of "Pedagogic Principles for the design of the SEISMO-Lab Educational Activities" and articulates the science-specific capabilities supported by the environment of the open school (see Table 2.1). These Pedagogic Principles provide a framework for the development of key competencies that are related with the Deeper Learning in Science, that is formed from a series of key competencies, namely creative problem solving, critical thinking, interest, and motivation in science and over all the development of the academic mindset.

[10] Sotiriou, Sofoklis & Bybee, Rodger & Bogner, Franz. (2017). PATHWAYS – A Case of Large-Scale Implementation of Evidence-Based Practice in Scientific Inquiry-Based Science Education. International Journal of Higher Education. 6. 8. 10.5430/ijhe.v6n2p8.

SEISMO-Lab will present such unique learning experiences emerging from the acquisition and the analysis of seismic data from numerous school-based seismometers. Using the tools of science, such as seismometers and analysis tools, students could become more familiar how scientists work on their research problems. In the framework of SEISMO-Lab a wide network of school-based scientific instruments will be created, and students will be involved in real-science activities. By engaging in scientific activities, participants also develop greater facility with the language of scientists; terms like hypothesis, experiment, and control begin to appear naturally in their discussion of what they are learning. In these ways, non-scientists begin to enter the culture of the scientific community.

Figure 2.3: *SEISMO-Lab network of school-based seismometers aims to simulate the process of scientific cooperation in the field of seismology. Through participation in the proposed activities students may gain appreciation of how scientists work together and the specialised language and tools they have developed. In turn, students also can refine their own mastery of the language and tools of science. Using the tools of science, such as seismometers and analysis tools, students could become more familiar with how scientists work on their research problems.*

2.2 Key pillars of the SEISMO-Lab Framework

Two are two pillars for designing and developing the SEISMO-Lab Framework for Establishing STEAM School Competence Labs: a new way of curriculum organisation and an offer of continuous support for empowering learners as creators that demonstrate their mastery in forms that surpass traditional instructional models.

2.2.1 Integration of Scientific Subjects

Educational approaches such as project-based and inquiry-based learning necessitate a reorganization of schools and curricula. This restructuring aims to enable students to transition more seamlessly from one subject to another, eliminating the constraints of traditional isolated lessons. Changing the dynamics of the learning process within classrooms also necessitates the adoption of new organizational models for schools. This shift is primarily a response to the highly structured nature of a typical school day, which is perceived by some as inhibiting effective learning.

This approach emphasizes collaborative efforts, critical thinking, and enhanced knowledge retention as three positive outcomes for students. Technology plays a central role in this design, with activities such as the integration of 3D printing in science classes and the incorporation of media production into humanities courses becoming increasingly prevalent. The ultimate objective is to help students comprehend the multifaceted intersections between diverse subject areas and equip them with a skill set highly sought after in today's contemporary workforce.

2.2.2 Shift from Students as Consumers to Creators

There is growing support for empowering students as creators that demonstrate their mastery in forms that surpass traditional schooling. A vast array of digital tools is available to support this transformation in K-12 education; indeed, the growing accessibility of technologies is giving rise to a whole new level of comfort with producing media and prototypes. Many teachers believe that honing these skills in students can lead to deeply engaging learning experiences in which students become the drivers of the learning process. Emerging instructional frameworks are encouraging teachers to use digital tools that foster creativity and problem solving. This trend also implies that teachers are increasingly becoming creators, too, and are therefore in the position to lead activities that involve developing and publishing educational content.

2.2.3 Evidence from Practice

Large scale initiatives as the Open Schools for Open Societies (http://openschools.eu) and Schools as Living Labs (https://www.schoolsaslivinglabs.eu/) have successfully demonstrated the potential of the abovementioned emerging trends to offer qualitative upgrades to school education. These initiatives form the reference points for the integration and the operation of the competence labs, like the SEISMO-Lab in the specific case. These initiatives have been funded under the Open Schooling Initiative of the European Commission that was launched back in 2016 following the publication of the Policy Report on Science Education for Sustainable Citizenship[11].

Open Schools for Open Societies

Open Schooling for empowering students to form their own learning pathways: where schools, in cooperation with other stakeholders, become an agent of community well-being; the walls around schools to come down but they remain strong, sharing responsibilities with other community bodies. Non-formal learning, collective tasks and intergenerational activities are strongly emphasized; school projects revitalized around a knowledge agenda in cultures of experimentation, diversity, and innovation. It is an open system, welcoming approaches from potential external collaborators; The school scans its external environment to respond quickly to challenges and opportunities; families are encouraged to become real partners in school life and activities; professionals from enterprises and civil and wider society are actively be involved in bringing real-life projects to the classroom. Partnerships are based on equality of relationships and opportunities for mutual learning; Relevant policy

[11] *European Commission, Directorate-General for Research and Innovation, Science education for responsible citizenship – Report to the European Commission of the expert group on science education, Publications Office, 2015, https://data.europa.eu/doi/10.2777/12626*

makers encourage policy buy-in and the mainstreaming of good practices and insights into policies, and hence sustainability and impact. Such partnerships foster expertise, networking, sharing and applying science and technology research findings across different enterprises (e.g., start-ups, SMEs, larger corporations).

The SALL aims to open-up schools to their local communities by transforming them in Living Labs. In this way, SALL proposes a new framework for schools across Europe to approach their science education programmes, to make STEM teaching more relevant, systemic, and inclusive for their students, collaborating with their local ecosystems and research centers, and with the active support and involvement of science centers and museums in this process. SALL proposes the living lab methodology as a new technique of unique value and possibilities for the development of open schooling activities linked to science learning. SALL brings together school communities, including teachers, students and their families, research institutions, science museums and centers, spaces of informal learning and open innovation, as well as policy makers, and engages them in intensive dialogue and mutual learning and exchange.

2.3 Context of Implementation

In the context of the project, participating schools will receive support in establishing an innovation agenda aimed at:

- **Promoting Collaboration with Science and Research Centers:** The SEISMO-Lab project advocates diverse models of collaboration between schools and science/research centers, focusing on science learning. An ecosystemic approach is proposed, aiming to capture the profiles, needs, contributions, and relationships of all school-related actors and elements. This facilitates the development of a sustainable innovation ecosystem operating within a comprehensive framework of organizational learning and the promotion of educational innovations.
- **Fostering Partnerships for Expertise and Real-Life Application:** The project partners, both individually and collaboratively, have a track record of developing, testing, and promoting innovative educational applications and approaches for European schools. These initiatives support the sharing and application of cutting-edge research findings in schools, fostering the development of 21st-century competencies through creative problem-solving, experiential learning, critical thinking, and creativity. Real-life projects, such as analyzing seismological data or constructing and using scientific instrumentation, are integrated to bring practical experiences into the classroom.
- **Teaching Science with a Focus on Gender Issues:** Instructional methods designed to enhance students' understanding and accommodate diverse educational approaches contribute to increased participation and performance of girls in advanced science classes. By respecting the individuality of students and implementing various methods in the classroom, the project aims to create gender-inclusive learning environments that cater to different learning styles.

2.4 Design Features of the SEISMO-Lab Educational Activities

The activities to be implemented in the participating schools are grounded in the fundamental aspects of creative learning, encompassing exploration, the dynamics of discovery, student-led initiatives, engagement in scientifically oriented queries, emphasis on evidence in responding to questions, formulation of evidence-based explanations, connection of explanations to scientific knowledge, and communication and justification of explanations. These elements endorse creativity as an integral component in the procedural and communicative facets of pedagogy, aiming to propose innovative teaching strategies that foster high student participation and empower them to generate imaginative possibilities.

Simultaneously, the SEISMO-Lab framework aligns with the core principles of the Responsible Research and Innovation (RRI) process: learners' engagement, unlocking their full potential, sharing results, and providing access to scientific archives, all while designing innovative activities for diverse learners.

In line with these principles, participating schools will champion a series of educational activities manifested as real-life projects. These projects will leverage innovative ideas and creativity, encouraging students to actively participate in the learning process and enhance their conceptual understanding across various scientific topics. The educational practices and strategies proposed seek to enable science educators, particularly those teaching late primary and early secondary levels, to identify or create creative activities and assemble them into interdisciplinary learning scenarios.

Within the SEISMO-Lab project, the proposed activities (SEISMO-Lab Demonstrators) embody four essential characteristics:

- The activity is situated, either physically or virtually, in a context that students recognize and are eager to understand.
- The activity must be authentic, immersing students in actions of practical and intellectual value, fostering a sense of agency.
- The activity taps into the external passions of both students and teachers, enhancing engagement by allowing students to explore areas of interest that matter to them.
- The activity enables ongoing learning outside the classroom, leveraging family members, peers, local experts, and online resources as research and critique sources.

These criteria serve as a valuable checklist for teachers designing their learning plans and suggest what a science classroom and school as an organization need to offer to become more engaging: innovative curriculum, meaningful projects related to local challenges, passion-led teaching and learning, and pervasive opportunities for research and constructive challenge.

These activities will be adapted collaboratively by the school community, involving representatives from educational providers, industries, civil society associations, and even students themselves. The collaborative approach will promote interactions and the integration of classrooms with broader society. Participating schools, encompassing both primary and secondary education levels, will select and adapt activities to suit the distinct needs of each level.

2.5 Viable Change: A route to the future

The SEISMO-Lab framework places a strong emphasis on effecting lasting and scalable changes in school settings. The proposed approach strives to establish robust school networks that are eager to share their experiences with others. Rooted in numerous national and international initiatives, this framework acts as a unique resource for reforming schools toward more effective environments. Anticipating the future and conducting isolated experiments are insufficient for education decision-makers. It is imperative to conceptualize specific, potent ways to change current systems.

System thinking in action, addressing sustainability and the need for contextual change, recognizes that contexts or systems evolve over an extended period due to major shifts in demographics, technology, and social forces. The SEISMO-Lab framework seeks to accelerate positive changes, such as the spread of professional learning communities, by conceptualizing sustainability and leveraging leadership to change the context. This involves increasing leaders' participation in broader contexts and fostering leadership in others.

The SEISMO-Lab framework aims to create new environments across the system through tri-level development: at the school, community, and the educational authorities. The following elements encapsulate sustainability within this ambitious agenda:

- **Lateral Capacity-Building Through Networks:** Investment in strategies that promote schools learning from each other.
- **Deep Learning:** Continuously addressing fundamental learning goals, such as thinking and problem-solving skills, teamwork, and learning across the curriculum.
- **Dual Commitment to Short-term and Long-term Results:** Pursuing short-term increases in student achievement while laying the foundation for long-term learning.
- **Cyclical Energizing:** Recognizing that capacity must be built over time and emphasizing monitoring and stimulating energy.
- **The Long Lever of Leadership:** Leaders fostering the development of other leaders and widening their sphere of commitment and participation.

The fundamental notion of mutual learning plays a pivotal role in propelling this ambitious agenda forward. Continuous learning, the pursuit of superior information, experiential learning, and the fostering of networks constitute indispensable elements for augmenting capacity and instigating transformative change. This approach is not limited to educational institutions but extends its reach to communities and transcends national borders, encompassing trilateral reforms. The ERASMUS+ program for school collaboration and exchanges offers unique opportunities for perpetual learning and knowledge dissemination, even on an international scale. Giving heed to the burgeoning knowledge base, employing problem-solving, facilitating reflective learning, nurturing networks of interaction, and broadening one's worldview are integral facets of capacity development and catalytic change.

Lastly, it would be a fundamental misconception, grounded in systems theory, to presume that the system must undergo change before individual action. Each of us constitutes an integral part of the system; there is no definitive "chicken or egg" scenario. We must establish connections with others to effect change within any segment of the system that we can influence. When advocating for the promotion of professional learning communities, it is imperative to link these efforts to broader issues, connecting the proverbial dots on a grander scale. Waiting for others to take the initiative virtually guarantees the perpetuation of the existing status quo. By adopting a proactive stance, individuals can inspire others and enhance the likelihood that the system will commence a transformative shift, thereby fostering novel breakthroughs.

Figure 2.4: *SEISMO-Lab Professional Development Course programme brought together 25 teachers from the participating countries to co-design the SEISMO-Lab educational activities. ERASMUS+ Programme and mobility actions offer a unique framework for such participatory activities.*

3 SEISMO-Lab Pedagogical Approach

3.1 Practices for SEISMO-Lab project Implementation

This section presents the pedagogical principles for the implementation of the SEISMO-Lab project and the design of the proposed activities. The cornerstone condition is a school-wide culture that focuses on learning and promotes the belief that everyone is collectively responsible for student outcomes. There are six practices common across the schools committed to open schooling. School heads and teachers must[12]:

• Support students
• Offer learning in Context
• Bridge learning to real world experiences
• Support learning everywhere
• Increase students' interest and motivation
• Design meaningful technology enhanced learning experiences

For teaching to shift to facilitate powerful learning experiences – where students are empowered and inspired, and learning is contextualised, connected to real life, wired, and extended beyond school – the role of the teacher must change to that of the facilitator of the learning process. He/she must fluidly in switching among a range of roles, including learning designer; facilitator; networker; and an advisor who coaches, counsels, mentors, and tutors depending on what is most needed to promote student learning.

3.1.1 Supporting students

Teachers must use approaches that help students become self-directed and responsible students rather than passive rule followers. The centrepiece of instruction is supporting students to develop their own learning paths -based on their needs and interests -, a process that entails seeking feedback, revising work, and regularly reflecting on the outcomes of their work, as well as on the choices and decisions made throughout the learning process. "Revision towards mastery" is therefore a key feature of the culture and the language used by schools committed to deeper learning[13]. Teachers provide feedback, as well as opportunities for students to receive feedback from peers. The support from external stakeholders, e.g., the seismology experts in the case of SEISMO-Lab, improving their work through rounds of feedback, revision and reflection encourages students to better understand the amount of effort required to produce high quality work. Working with real scientific data offers numerous opportunities for such interventions (e.g., comparison of the students' findings with the data from the national or Mediterranean seismic network, optimization of the findings).

3.1.2 Learning in Context

Teachers should bring the theoretical aspects of the intervention in context so to be coherent to help students to realize the strong relations between the school curriculum

[12] Martinez, M. et al. 2014. How Deeper Learning Can Create a New Vision for Teaching. National Commission on Teaching and America's Future
[13] Lenz, Bob., Wells, Justin, Kingstone, Sally. 2015. Transforming Schools Using Project Based Learning, Performance Assessment and Common Core Standards. San Francisco, CA: Jossey-Bass.

themes with real science. This could act as a catalyst for the active involvement of the students. Teachers (following the SEISMO-Lab Demonstrators) will involve students in activities and projects that are relevant to their lessons.

3.1.3 Bridge learning to real world experiences

The SEISMO-Lab Demonstrators should ensure that there are frequent opportunities for students to experience the working conditions of the scientists (e.g., through visits to research centres and infrastructures) and to be involved in problem solving tasks by interacting with professionals and experts in relevant fields, taking on a professional role when doing a project. Interaction with authentic science using seismometers and their recordings, familiarity with the network's operation, acquisition of significant technological knowledge, and the writing of scientific papers are expected to play a crucial role in cultivating autonomy, initiative, and inquiry skills in students. Simultaneously, the opportunity for children to come into contact with modern methods of studying earthquakes, understanding the unique phenomena occurring inside the Earth, the process of making observations with a seismometer, and meeting specialized personnel from a large scientific institution can serve as a driving force and guide students towards the professional orientation they will choose in the future, exposing them to innovative professions and career profiles.

3.1.4 Learning Everywhere

By participating in the activities of the project and utilizing the tools it will provide (interactive platform, scientific datasets, analysis tools), students will gain an understanding of the complete scientific process: experiment design, data collection and analysis, and publication of results within the student scientific community. The implementation of the proposed action combines exploration and experimentation by encouraging students to use the scientific method to solve problems, create, and collaborate.

LEARNING WITH AND FROM THE EXTERNAL ENVIRONMENT AND LARGER SYSTEM

- The school scans its external environment to respond quickly to challenges and opportunities
- The school is an open system, welcoming approaches from potential external collaborators
- Partnerships are based on equality of relationships and opportunities for mutual learning
- The school collaborates with parents/guardians and the community as partners in the education process and the organisation of the school
- Staff collaborate, learn and exchange knowledge with peers in other schools through networks and/or school-to-school collaborations
- The school partners with higher education institutions, businesses, and/or public or non-governmental organisations in efforts to deepen and extend learning
- ICT is widely used to facilitate communication, knowledge exchange and collaboration with the external environment

Figure 3.1: *Modelling and Growing Learning Leadership. Source: OECD/UNICEF (2016): What makes a school a learning organisation? A guide for policymakers, school leaders and teachers, p.8.*[14]

3.1.5 Increase students' interest and motivation

The SEISMO-Lab Demonstrators will need to be localized to meet the needs of the involved classrooms and schools in the participating countries. Although the earthquake is a common phenomenon that affects the local communities, still the level of interest of the inclusion of the specific theme in the curriculum is different. This must be considered. For example, the project will be implemented in the framework of the recently introduced "Skills Labs"[15] activity in the Greek Curriculum. The Skills Labs represent an innovative, dynamic, and educational action that involves the addition of new thematic units, focusing on skills, to the compulsory curriculum of Primary and High School, utilizing contemporary and innovative teaching methods. A fundamental principle of the Skills Labs is to combine the cognitive domain of the Curriculum with the development of essential abilities of students with the aim of shaping them into free and responsible citizens. The purpose of the Skills Labs is to enhance the cultivation of soft skills, life skills, and technology and science skills in female and male students. The specific objectives of the Skills Labs include learning through collaborative, creative, and critically reflective teaching methodologies, as well as strengthening life skills, mediation, and responsibility. They offer a great opportunity for the implementation of SEISMO-Lab project.

3.1.6 Design meaningful technology enhanced learning experiences

SEISMO-Lab Demonstrators purposefully incorporate technology to enhance learning; regularly employ technology tools to support student learning and to facilitate their own learning path.

3.2 Key Conditions for establishing an Open Schooling Culture

To enable a shift in teaching towards fostering powerful learning experiences, such as those mentioned earlier—where students feel empowered and motivated, and learning is happening in context, connected to real-life, technologically supported integrated, and extends beyond the confines of the classroom—the role of the teacher needs to transform into that of a learning strategist. To effectively serve as a coach of learning, a teacher should seamlessly navigate through various roles, including being a learning designer, facilitator, networker, and an advisor who coaches, counsels, mentors, and tutors based on what is most conducive to promoting student learning.

In the implementation of SEISMO-Lab, it is crucial for national coordinators, school leaders, and teachers to acknowledge the key conditions that support the development of an open schooling culture and strategies. These conditions are sequential and interdependent, building upon one another. The foundational condition is a school-wide culture that prioritizes learning and fosters the belief that everyone shares collective responsibility for student outcomes.

[14] OECD (2016) What makes a school a learning organisation? Directorate for Education and Skills. (https://www.oecd.org/edu/school/school-learning-organisation.pdf)

[15] https://iep.edu.gr/el/psifiako-apothetirio/skill-labs

3.2.1 Introducing a new learning culture

To begin with, it is essential to foster a learning culture that recognizes the importance of acquiring knowledge. This culture should also emphasize students' need to develop effective learning skills, become self-directed learners, and cultivate an academic mindset that can potentially steer them toward scientific careers in the future. Establishing such a culture is primarily achieved through the explicit definition and communication of core values. These values should be clearly visible in the school's design, the orientation process for students, the content of assessments, and the consistent use of language throughout the school, including displayed materials on the walls. The embodiment of these core values is evident in various aspects, ranging from the language employed by teachers and students to discuss learning to the school's engagement with the broader community.

3.2.2 Shared responsibility for students' learning

The correlating condition that supports teaching in an open school is a culture where everyone shares collective responsibility for student learning. This culture needs to be intentionally cultivated for both students and teachers. It is typically fostered by establishing relationships that ensure students are well-known by both adults and peers. Moreover, it involves creating regular and systematic opportunities for ongoing conversations among teachers, students, peers, and other adults.

3.2.3 Build on trust and professionalism

Moreover, it is crucial to establish a culture of trust and professionalism as a fundamental condition supporting learning in an open school environment. The transformation in culture is paramount to ensuring that teachers feel supported and empowered to embrace new roles, and to guarantee that daily work and interactions align with the open schooling plan and vision.

Trust is empowering, allowing individuals to bring out their best qualities and fostering a sense of shared accountability among the staff. Shared accountability can foster increased trust among teachers and between teachers and school leaders. School leaders who trust their teachers and treat them as professionals may involve them in the leadership of the school, granting substantial influence in school-based decisions, particularly regarding teaching and learning matters. In this collaborative environment, teachers often take on various roles, such as grade-team coordinator, teacher mentor, teacher leader, and coach—formally and informally. In this new paradigm, teachers may also assume responsibilities typically reserved for principals, including staff hiring, creating school schedules, establishing partnerships with external organizations or businesses, and even engaging with funders.

In a culture of trust and professionalism, school leaders appreciate the vast experiences and wealth of knowledge possessed by teachers, actively encouraging their involvement in the design and customization of professional development. As teachers play a role in designing their own professional development, they become highly engaged, collaborating effectively with colleagues to ensure that professional development is growth-driven, collectively crafted, context-specific, and integrated into the school environment.

3.2.4 Offer opportunities for teachers to collaborate

These cultural and role shifts necessitate environments that more deeply cultivate the open schooling culture and acknowledge and allocate time for teachers to collaborate. During these collaborative sessions, teachers can tap into each other's expertise to design or refine meaningful learning experiences for students. They can address challenges affecting both the classroom and the school, strategize ways to enhance their individual practices, and improve student learning outcomes.

Structured opportunities for collaboration can manifest as teacher-led and school-integrated professional development, facilitated by peers or external entities, focusing on specific pedagogical approaches. These sessions may involve feedback derived from classroom observations conducted by instructional coaches or fellow teachers, offering insights into each other's teaching practices. Additionally, teachers can utilize their structured collaborative time to identify and share technology tools, apps, or resources for assessing students' mastery of content, critical thinking, and other skills. This collaborative effort enables the personalization of instruction to address the unique learning needs of each student.

4 Implementation Strategies

In Chapters 2 and 3, we have outlined the SEISMO-Lab framework, the intended implementation context, and the key features and characteristics of project activities. We've discussed the practices and necessary conditions to foster the development of an open culture within school communities. Our goal has been to succinctly outline the main challenges associated with introducing the SEISMO-Lab framework in schools across Europe and to delineate the features of teaching in open schooling environments. This ensures that participating schools, along with school heads and teachers, have a comprehensive understanding of the various aspects and conditions of the proposed intervention.

Moving forward, our next step is to define practical strategies tailored for the consortium, school heads, and individual teachers. These strategies aim to support local schools as they undergo the transformation into open schooling environments during the implementation of the SEISMO-Lab framework. The guidance provided will extend to schools and local-level stakeholders throughout the pilot implementation phase of the project.

4.1 A localised Approach

The SEISMO-Lab strategies encapsulate the overarching methodology of the project in its endeavour to provide optimal support to educational institutions as they undergo transformations, restructuring, and revitalization toward the establishment of a more decentralized, community-oriented, and socially conscious learning environment. Within this paradigm, educational institutions will facilitate an open, more efficient, and effective collaborative development, co-creation, and utilization of educational resources, tools, and services tailored to individualized science education and instruction. These foundational components will serve as the cornerstone elements for pioneering student initiatives, which, exemplified as best practices, are denoted as the SEISMO-Lab Demonstrators within the project's framework.

In the ensuing section, a series of strategies will be delineated, each geared toward specific educational contexts with respect to openness, assimilation of innovation, and ethical stewardship. These strategies are designed to provide schools with guidance in the implementation of the SEISMO-Lab framework and its associated methodologies.

4.1.1 Openness for beginners: from isolated efforts to whole school action plans

Schools in their preliminary stages of adopting innovative practices and fostering openness are provided with tools for needs analysis. These tools are aimed at identifying areas necessitating immediate attention and modernization, encompassing aspects such as Continuous Professional Development (CPD), the integration of information and communication technology (ICT), development of educational materials, and participation in collaborative networks with peers and other stakeholders. The project's partners, including science centers and museums, collaborate with these schools to co-create an initial Educational Scenario (detailed templates available in Chapter 6 to facilitate the implementation of different innovative approaches to the school settings) that outlines the trajectory of students in their scientific discovery and exploration. These scenarios will form the basis for the development of the SEISMO-Lab Demonstrators.

Subsequently, the school assembles a core group of educators designated as "Change Agents." These individuals are innovative teachers who share the school community's vision and play a pivotal role in propelling the institution toward the next level of educational advancement.

What is the mission of a change agent?

- **A pioneering teacher who leads the team of participating teachers from each school, and:**
- Takes initiative to implement innovative practices that aim to have a **long-term effect** on the development of the **school as a whole**.
- Develops a **strategy** for involving and disseminating the results of innovative practices to the **whole school community.**
- Develops a strategy for **dealing with resistance to change**
- **Reflects** on the progress of organisational changes.
- **Explains why innovation is important to ensure long-term success.**

At this stage, the SEISMO-Lab project is pioneering innovative scenarios to experiment with scientific data, resources, and cutting-edge technological services. The project aims to create a rich database of creative initiatives, providing access to high-quality resources, guidelines, and support. This includes coordination of action plans with funding opportunities for the realization of school action plans, emphasizing teachers' professional development and the adoption of School Development Plans for participating schools (see Chapter 5). The strategy is to stimulate teaching and learning processes based on effective instructional models for science education, as outlined in Chapter 6. This phase allows teachers the necessary time to revisit their perspectives and experiment in their classrooms. The focus is on the inquiry as a powerful pedagogical approach that leads to the development of student-led science projects.

Community-building tools assume a pivotal role during this phase, serving to foster relationships and collaborations within schools, as well as between schools and local stakeholders. These tools contribute to the localization of successful experiences, essentially converting best practices into locally-tailored projects. They aid in comprehending how institutional structures, hierarchies, and learning cultures adapt to change. Teachers and students, while embracing well-crafted educational methods, encourage their utilization and dissemination, thereby nurturing educational innovations and communities of practice.

Teachers are expected to engage in thoughtful reflection on organizational transformation and learning cycles as part of the implementation process. The objective is to encourage teachers to give back to their communities, thus fostering fresh collaborations and networking. Emerging pedagogical practices and educational encounters should inspire exploration, reflection, and the creation of content suitable for dissemination beyond the educational context, permitting evaluation by others within the educational institution. Prior educational experiences can serve as a breeding ground for subsequent ones derived from initial projects and ideas.

In assessing a school's current requirements concerning innovation and openness, an evaluation of pertinent strengths and weaknesses is undertaken. The proliferation of online communication and communities offers distinct advantages for peer-based learning and professional development among teachers. Online communities address constraints posed by traditional training methods, providing opportunities for both synchronous and asynchronous engagement, while ensuring equal participation of all community members.

Furthermore, online communities grant access to the latest educational technology and insights, shared through the exchange of best practices.

SEISMO-Lab will facilitate the creation of diverse online communities dedicated to supporting teachers in the development, utilization, and dissemination of digital resources pertaining to science student projects, with a particular emphasis on social responsibility. Communities focused on specific Responsible Research and Innovation (RRI) principles and their integration into the school's cultural fabric hold substantial importance and align with the overarching strategy of promoting openness within schools.

4.1.2 Strategies for competent schools

More competent schools exhibit a robust capacity for innovation, actively undertaking local projects and activities. However, there is a notable tendency for these schools to operate in relative isolation, often overlooking valuable opportunities to incorporate external resources into their plans and programs. Teacher communities primarily function at the local level, with limited sharing of content and materials produced with external communities. The implementation of educational scenarios becomes especially pertinent in this context, serving as a useful tool for school management committed to initiating activities that enlighten educational staff about the added value of the innovation process.

The introduction of SEISMO-Lab Demonstrators can guide schools in evolving into incubators of innovation. Emphasis is placed on employing knowledge management techniques, such as sharing insights within participating school communities, synthesizing evaluations, and expediting diffusion within national agencies to reach a broader audience. Observations derived from the use of data by school communities, the development of teacher competence profiles, locally created content, and community interactions will contribute to establishing a unique database for future recommendations and identifying best practices.

SEISMO-Lab will propose initial scenarios for integrating the project's methodology into participating schools. Schools are encouraged to establish networks for implementing suggested activities. Providing training on preparing eTwinning projects or KA1, KA2 Erasmus+ mobility, and school-based project applications could serve as an effective means to introduce schools to the international cooperation field. Simultaneously, substantial resources can be allocated to the professional development program of the school. SEISMO-Lab Demonstrators, accessible on the project's website, can assist innovative schools in transforming their ideas into new localized projects, offering solutions for both the school and its community. This approach helps bridge the gap between formal and informal learning settings, creating new opportunities for personalization at various levels (student, teacher, school).

Collaboration with partner research and science centres will support the design and development of new localized educational scenarios, providing a framework for the implementation of large-scale projects beyond the school walls.

4.1.3 Schools as RRI-enriched seismology education hubs

In this category, schools have established a well-defined innovation plan and have cultivated a culture of knowledge sharing, along with strong collaborations with other schools and external stakeholders. The SEISMO-Lab strategy for these schools, focuses on the integration of the Responsible Research and Innovation (RRI) culture within the school environment. The realm of research and innovation (R&I) encompasses all essential stakeholders, including policymakers, researchers, industry and commerce representatives, science educators, civil society organizations, and the broader public. To facilitate this integration, the development of SEISMO-Lab strategies involves the utilization of tools provided by the RRI Tools initiative, which guides the introduction of RRI principles into various educational organizations, encompassing both formal and informal learning sectors.

A handbook, complemented by self-reflection tools, will be made available to teachers with the primary goal of seamlessly incorporating RRI practices into schools, with a particular emphasis on STEM disciplines (science, technology, engineering, and mathematics). The alignment of RRI principles with innovative teaching methods, such as Inquiry-Based Science Education (IBSE) and structured research school projects, signifies a convergence toward a shared RRI learning approach.

In addition to the utilization of SEISMO-Lab Demonstrators and support materials at the school level, consortium partners will offer recommendations to school leaders for comprehensive and strategic school improvement. Some examples of these recommendations may include:

- Suggestions regarding specific RRI principles to be incorporated into the School Development Plan, alongside relevant SEISMO-Lab Demonstrators that address local social issues.
- Recommendations for establishing effective collaborations with organizations like museums, science centers, research institutions, businesses, industries, and local communities.
- Proposals for identifying potential partner schools with similar or complementary profiles to foster collaborative efforts and mutual enhancement.
- Guidance on designing professional development courses tailored to address the specific competency needs of teaching staff.
- Advice on enhancing the use of information and communication technology (ICT) in teaching practices, including the analysis of educational designs and offering personalized suggestions based on the competency profiles of teaching staff.
- Recommendations for educational designs, drawing from successful models employed in schools with similar innovation profiles. These recommendations, presented as school innovation actions, will be clearly defined and implemented by school leaders.

In this category, schools have effectively implemented an innovation plan, fostering a culture of knowledge sharing and maintaining robust collaborations with other schools and external stakeholders. The SEISMO-Lab strategy for these schools underscores the integration of the Responsible Research and Innovation (RRI) culture within the school environment. Research and innovation (R&I) encompass all key stakeholders, including policymakers, researchers, industry and commerce representatives, science educators, civil society organizations, and the broader public.

A set of evaluation tools, complemented by self-reflection tools, will be made available to teachers with the primary objective of seamlessly integrating RRI practices into schools, with a particular focus on STEM disciplines (science, technology, engineering, and mathematics). The alignment of RRI principles with innovative teaching methods, such as Inquiry-Based

Science Education (IBSE) and structured research school projects, signifies a convergence toward a shared RRI learning approach.

In this context, schools equipped with such accelerators are well-positioned to not only endorse and implement gender equality principles within their profiles and science teaching but also to play a pivotal role in fostering collaborations with parents, local groups, businesses, and other stakeholders. Through these collaborations, schools can offer solutions and resources, enlightening, training, and supporting local stakeholders who seek meaningful change.

4.1.4 Forward-looking scenarios for seismology learning hubs

The SEISMO-Lab consortium is dedicated to proposing strategies for educational institutions that have already achieved a high degree of openness in their operational practices, with a dual focus in mind. Firstly, sustainability is recognized as a pivotal avenue for the future within the SEISMO-Lab framework, with a strong emphasis on effecting enduring and far-reaching changes in school environments. The proposed approach seeks to establish robust school networks that are prepared to share their experiences with others. Secondly, acknowledging the imperative need for evolution in educational systems, the consortium underscores the principles of experimentation, independence, and knowledge sharing. Schools should have the freedom to experiment, evaluate outcomes, discontinue unsuccessful or excessively costly experiments, derive lessons from them, and disseminate and replicate successful initiatives on a larger scale. Schools that have achieved higher levels of openness are expected to act as catalysts for this transformative process and will require significant support in fulfilling this crucial role.

The SEISMO-Lab framework, complemented by the online platform and teachers' space, will facilitate the development of school networks with these highly open schools at their core, serving as reference points. Sustainability, in this context, extends beyond the continuity of the open schooling model; it concerns how specific initiatives can be developed without hindering the progress of others in the surrounding environment, both presently and in the future. Sustainability, from this perspective, involves the transformation and advancement of the social environment. The SEISMO-Lab framework places its focus not on the proliferation and development of individual schools, but on the creation of new educational environments across the system through tri-level development—at the school, community, and national levels. The concept of learning from one another becomes paramount in advancing this ambitious agenda, particularly emphasizing tri-level reform. School cultures are enriched when teachers within the school continually engage in mutual learning.

Within this paradigm, open schools are transitioning toward an outcome-based education model, where flexibility and diversity serve as guiding principles. School curricula are tailored to local needs, and student-led projects become the norm. In contrast to the prevailing global emphasis on scientific literacy, numeracy, and structured knowledge, open schools in this environment place value on all aspects of an individual's personal development—whether it be moral, creative, knowledge-based, or skills-oriented. While the prevailing trend in European educational systems leans toward consequential accountability systems, wherein school success or failure is often determined by standardized tests and external evaluations, open schools take a different path. They prioritize trust through professionalism, fostering a culture within the education system that values the professionalism of teachers and school leaders in determining what is best for students and reporting on their learning progress.

Table 4.1: *The guiding principles of a conventional school versus an open school environment.*

Standardisation Strict standards for schools, teachers and students to guarantee the quality of outcomes.	**Flexibility and diversity** School-based curriculum development, steering by information and support.
Emphasis on literacy and numeracy Basic skills in reading, writing, mathematics and science as prime targets of education reform.	**Emphasis on broad knowledge** Equal value to all aspects of individual growth and learning: personality, morality, creativity, knowledge and skills.
Consequential accountability Evaluation by inspection.	**Trust through professionalism** A culture of trust on teachers' and headmasters' professionalism in judging what is best for students and in reporting of progress

5 Implementation Parameters

5.1 Exploit Resource-Based Learning

5.1.1 Overview of Resource-Based Learning

Subjects like science provide an opportunity to exploit Resource-Based Learning (RBL) alternatives, expanding both the materials and the methods used in teaching and learning. Resource-based learning "…involves the reuse of available assets to support varied learning needs"[16]. Several factors make RBL viable: 1) increased access to resources in a variety of contexts not previously available; 2) resources are increasingly flexible in their manipulation and use; and 3) economic realities dictate that resources become more readily available, useable, and shareable across a variety of contexts and purposes.

5.1.2 Components of Resource-Based Learning

RBL features four basic components: enabling contexts, resources, tools, and scaffolds. Taken together these components enable teachers to create and implement enriched learning experiences and courses with considerable diversity and flexibility.

Table 5.1: *Components and Characteristics of Resource-Based Learning*

RBL Components	Key Characteristics
Enabling contexts	Imposed: Teacher or external authority determines goal. Induced: Learner or learner and teacher determine the goal.
Resources	People, things or ideas that support the learning process.
Tools	Objects used to help facilitate the learning process. Range from processing to organisation to communication tools.
Scaffolds	Support that is faded over time. Includes conceptual, metacognitive, procedural, and strategic scaffolds.

Table 5.1 provides an overview of key characteristics of the RBL Components. Each component is described briefly in the following paragraphs.

5.1.3 Enabling contexts

Enabling contexts form and facilitate the situation or problem that orients students to recognise problems and frame their actual learning needs. By creating such contexts of implementation, meaningful learning can occur through the resources provided or obtained. Enabling contexts can be imposed, induced, or generated. For example, the implementation of the SEISMO-Lab Demonstrators will impose the cooperation between students from different schools as the estimation of the epicentre of an earthquake requires the acquisition of data from different seismometers operated by different school communities across the network. While teachers are focusing on the use determined objectives (e.g., National Curriculum) imposed contexts clarify expectations and guide their instructional strategies implicitly. Induced contexts introduce a domain where problems are situated, but not specific problems are expected to be addressed. A typical scenario enables multiple problems or issues to be generated or studied based on different assumptions, topical

[16] https://en.wikipedia.org/wiki/Resource-based_learning

relevance, and the context of use. The organisation of Hackquakes is an example of an induced context of implementation in the case of SEISMO-Lab (see Figure 5.1). In generated contexts, specific problem contexts are not provided; rather, the teacher develops an interpretive context based on the needs of his or her classroom. To facilitate this process the project team will present a few templates for the design and the development of the SEISMO-Lab Demonstrators to allow for a variety of options and instructional approaches to be used by the teachers.

Figure 5.1: *The idea behind the organisation of a Hackquake event was to involve students in an educational activity that would encourage them to use open research data and more precisely the constant flow of data coming from the School Seismograph Network. In that case it would be the development of an app that would work as an Early Warning System in the event of an earthquake which could potentially have a major impact on the society, and it would stand as a representative example of the benefits of citizen science towards the society.*

5.1.4 Resources

Resources maybe provided by a more knowledgeable person (e.g., researcher, teacher) to assist students in extending or broadening knowledge or understanding. Resources may also be gathered by the students in the framework of the learning process or while they are trying to solve complex problems. The outcomes of students work consist also very useful resources. Given varying contexts of use, the utility of a resource may change dramatically depending on the situation. As resources increasingly become both relevant to learners' need and accessible, they gain greater utility.

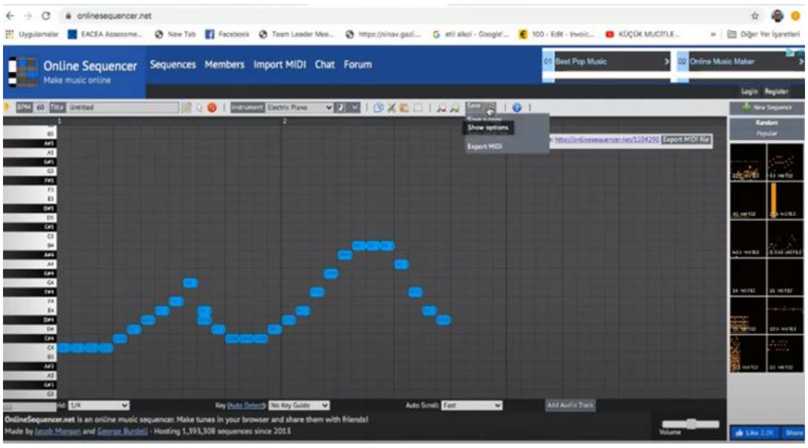


Figure 5.2: *Using sound editing applications, we can change the frequency of the seismic wave so that it can be heard by the human ear. With the help of a synthesizer software the seismic waveform is converted to musical notes and the sound of the earth is compiled.*

5.1.5 Tools

Tools enable students to engage with and manipulate scientific resources. Tool uses vary with the enabling contexts and user intentions; the same tool can support different activities and functions. Eight types of tools are used in RBL: processing, seeking, collection, organisation, integration, generation, manipulation, and communication. Processing tools help students to manage the cognitive demands associated with RBL. Processing tools, such as self-directed learning systems, for example, enable learners to work with ideas, extending their cognitive abilities and reducing the need to “remember” or engage in unnecessary mental manipulation. Seeking tools (e.g., keyword searches, topical indexes, search engines) help to locate and access resources. Seeking tools can also be specific to a particular context. SEISMO-Lab will design an interactive online platform that will function as a virtual hub for sharing the seismic data from the school-based seismometers. It will offer the possibility of utilizing data collected and stored by the seismometers in real-time and everyone will be able to select seismic events (by time and region) and "download" their recordings for analysis at the different stations of the network. On the project platform, in addition to educational materials for teachers (lesson plans, suggested activities, etc.), material to support the management of the educational tool will be provided, targeting teachers and students. The research team of the project will suggest educational activities and provide the necessary supporting material (application guide, required software, useful web addresses, etc.) for educators and students. Thus, teaching concepts and elements from the natural sciences is possible with the active participation of students within an interdisciplinary framework.

5.1.6 Scaffolding in RBL

Scaffolding is a crucial pedagogical concept in the context of RBL, providing support and structure to learners as they engage with diverse resources. Here are three types of scaffolds employed in RBL:

Conceptual Scaffolds:

Definition: Conceptual scaffolds guide learners by directing their attention to relevant knowledge or organizational aspects related to a problem or topic.

Examples: Traditional worksheets have been utilized in formal learning to provide conceptual scaffolding. In the digital realm, communication tools can offer leading questions or scenarios, setting a context for learners on a website. The inquiry-based approach often employs conceptual scaffolding to aid learners in exploring new areas and constructing understanding.

Metacognitive Scaffolds:

Definition: Metacognitive scaffolds support the cognitive demands inherent in RBL, assisting learners in initiating, comparing, and revising their approaches.

Examples: Scenarios or cases are frequently employed to focus and guide learners as they explore and seek to comprehend. These scenarios present ideas for consideration and serve as checkpoints for learners to assess their understanding. Metacognitive scaffolding prompts learners to reflect on what they know and understand.

Procedural Scaffolding:

Definition: Procedural scaffolding assists learners in navigating and emphasizes how to use the features and functions of a learning environment.

Examples: WebQuests are a notable example of procedural scaffolding, extensively utilizing guidance on procedures. Developed by Bernie Dodge, WebQuests optimize learners' time, focusing on using information rather than searching for it. Procedural scaffolds, by addressing the "how to" aspects, liberate cognitive resources for other crucial learning activities such as problem-solving and higher-order thinking.

In summary, these scaffolding strategies in RBL serve distinct purposes: conceptual scaffolds direct attention to relevant knowledge, metacognitive scaffolds facilitate reflection and revision of approaches, and procedural scaffolds guide learners in utilizing learning environments effectively. The integration of scaffolding enhances the overall learning experience, making RBL more accessible and conducive to meaningful engagement.

5.1.7 Qualitative Upgrade of Teaching and Learning with RBL

RBL introduces opportunities for a qualitative upgrade in both teaching and learning, leveraging the affordances of available and emerging technologies across diverse settings. Here are key features and benefits of RBL:

- **Access to Diverse Perspectives:** RBL allows access to a multitude of perspectives on a given phenomenon, offering a more comprehensive understanding. Unlike traditional textbooks, digital resources in RBL enable extended access to diverse perspectives, fostering a more inclusive and nuanced view of events and processes.
- **Versatility in Implementation:** RBL can be implemented in various contexts, transforming the nature and role of traditional resources. It is applicable in formal and informal settings, across electronic and physical platforms, in specific or distributed locations, and without limitations on time.
- **Facilitation of Learner-Centered Approaches:** RBL tends to focus on individualized learning approaches, empowering students to access electronic, print, and physical resources. Learner-centered approaches are not confined to one-to-one interactions; students may collaborate in small groups or classes while still benefiting from personalized learning experiences.
- **Cultivation of Key Skills and Competencies:** RBL cultivates essential skills for learners in the Knowledge Society, where identifying crucial information and understanding its relevance in different contexts is paramount. Students develop critical thinking, problem-solving, reflection, and self-direction skills as they navigate through a vast array of resources and evaluate their veracity and utility. Open-ended questions in RBL stimulate investigation, encouraging students to engage in critical examination and manipulation of multiple resources.
- **Encouragement of Information-Seeking and Evaluation Skills:** RBL encourages students to actively seek information and evaluate its credibility and usefulness. Learners must discern between "knowing that" and "understanding why," enhancing their ability to critically assess information in an era of abundant, often conflicting data.
- **Considerable Potential:** RBL offers considerable potential by addressing context-specific, user-centered learning needs. Individuals, whether teachers or learners, can harness the available information systems, refine their learning strategies, and adapt based on their progress.

In summary, RBL transforms traditional learning paradigms by providing access to diverse perspectives, accommodating various contexts, promoting learner-centered approaches, cultivating essential skills, and unlocking the considerable potential of information systems for teaching and learning enhancement.

5.2 Universal Design for Learning in SEISMO-Lab Project

5.2.1 Universal Design for Learning Guidelines

Universal Design for Learning (UDL)[17] is a comprehensive framework employed by the SEISMO-Lab project to enhance and optimize teaching and learning experiences for all

[17] https://www.cast.org/impact/universal-design-for-learning-udl

students. Rooted in scientific insights into human learning, UDL principles aim to create inclusive and meaningful educational pathways.

The UDL Guidelines[18] serve as a crucial tool in implementing UDL within the design of SEISMO-Lab Demonstrators, offering concrete suggestions. They are applicable to different curricula, and they can be localised to serve teachers and students working in different educational systems. They are not meant to be a "prescription" but a set of suggestions that can be applied to reduce barriers and maximize learning opportunities for the students. They can be mixed and matched according to specific educational objectives and can be applied to content areas and contexts.

The framework revolves around three key principles:

Provide multiple means of Engagement:
Rationale: Recognizing that students are diverse in their sources of motivation and engagement due to factors like neurology, culture, personal relevance, and background knowledge.
Implementation: Offering a variety of options for engagement, acknowledging that different learners thrive in different contexts, such as spontaneous and novel experiences or structured routines.

Provide multiple means of Representation:
Rationale: Acknowledging variations in how students perceive and comprehend information, influenced by factors like sensory disabilities, learning disabilities, and language or cultural differences.
Implementation: Ensuring multiple representations of content to cater to diverse learning styles, including visual, auditory, and tactile approaches, fostering deeper understanding and connections between concepts.

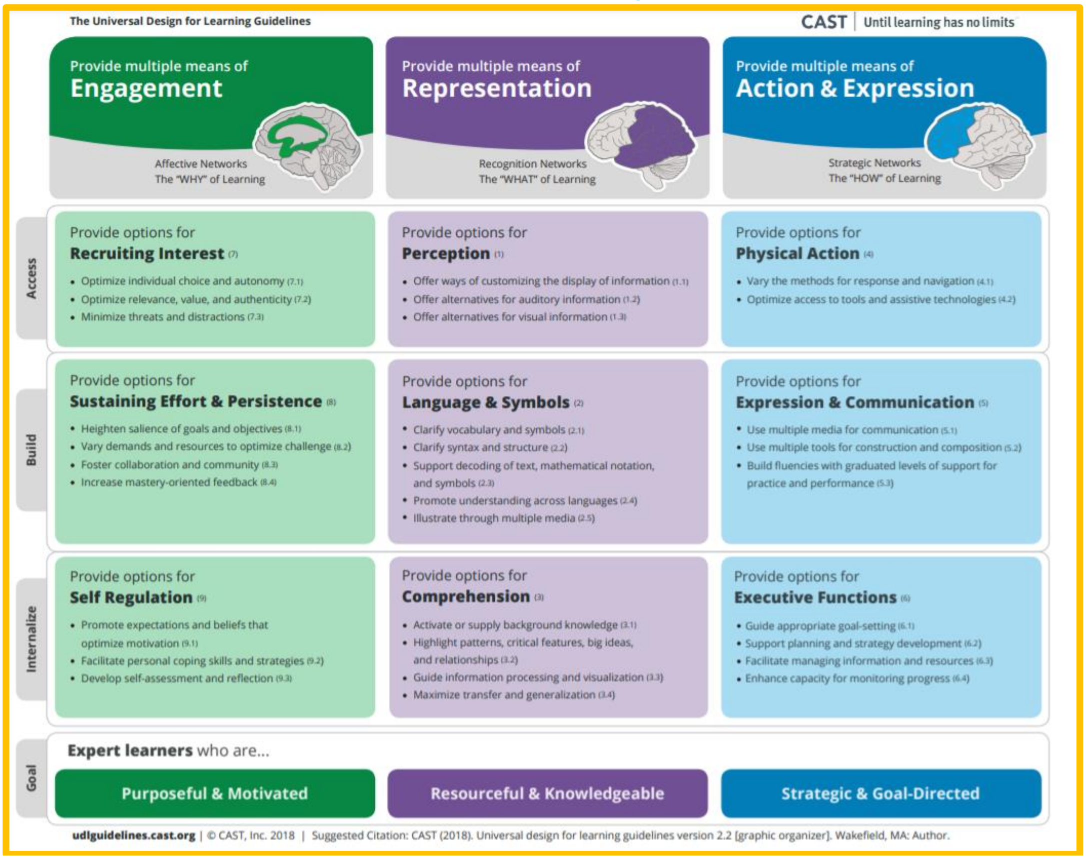
Provide multiple means of Action & Expression:
Rationale: Acknowledging differences in how students navigate learning environments and express their knowledge, considering factors like movement impairments, executive function disorders, and language barriers.
Implementation: Offering diverse options for students to demonstrate understanding and express themselves, recognizing that individuals may excel in different modes such as written text, speech, or other means of communication.

The UDL Guidelines (Table 5.2) are structured both horizontally and vertically. Vertically, they align with the three UDL principles: engagement, representation, and action and expression. These principles further break down into Guidelines, each containing corresponding "checkpoints" that offer detailed suggestions.

This framework ensures a systematic and comprehensive approach to implementing UDL in educational design, emphasizing inclusivity and accessibility for all learners.

[18] https://udlguidelines.cast.org/more/about-graphic-organizer

Table 5.2: *The Universal Design Guidelines*



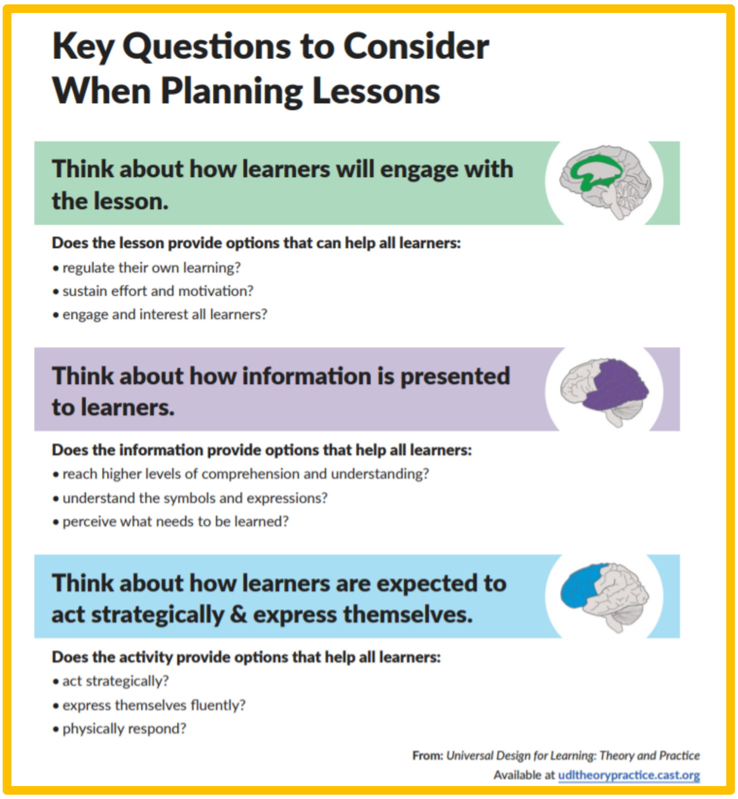
The Guidelines are also organised horizontally. The "access" row includes guidelines that suggest ways to increase access to the learning goal by recruiting interest and by offering options for perception and physical action. The "build" row includes the guidelines that suggest ways to develop effort and persistence, language and symbols, and expression and communication. Finally, the "internalise" row includes the guidelines that suggest ways to empower learners through self-regulation, comprehension, and executive function. Taken together, the Guidelines lead to the goal of UDL: to develop "expert learners" who are, each in their own way, resourceful and knowledgeable, strategic and goal-directed, purposeful and motivated.

5.2.2 Applying in SEISMO-Lab

In accordance with the UDL approach, the SEISMO-Lab project seeks to incorporate the principles of inclusivity within the educational framework of the SEISMO-Lab Demonstrators. UDL serves as a guiding framework to achieve this objective by offering a comprehensive strategy for developing curricula and educational activities that cater to the diverse needs of all students right from the outset. This is achieved by providing multiple avenues for information presentation, accommodating various language preferences, mathematical representations, and symbols, supporting diverse comprehension methods, and allowing for multiple modes of student action and expression. Furthermore, UDL extends to encompass options for physical interaction, communication methods, executive function variations, diverse engagement approaches, techniques for arousing interest, strategies to sustain effort and persistence, and mechanisms for self-regulation, such as facilitating personal coping skills and strategies.

Therefore, UDL becomes an integral component of the fundamental digital literacy skills that all students cultivate when incorporating SEISMO-Lab into educational settings. The federated approach we propose for this project is the linchpin for advancing accessibility and universal design, ensuring that education is inclusive and accessible to a broad spectrum of students.

Table 5.3: *Key issues to consider when design the SEISMO-Lab Demonstrators*



Embracing this approach would stimulate the creation of specialized tools aimed at tackling the most challenging accessibility barriers. By integrating universal design principles into the SEISMO-Lab, it becomes possible to comprehensively address a diverse array of accessibility requirements and issues. Moreover, it serves as a catalyst for digital solution developers, compelling them to embed accessibility considerations as a fundamental aspect of their design process from the project's inception. In Table 5.3, we outline the pivotal considerations that the project team and the educational community should take into account when designing the SEISMO-Lab Demonstrators.

5.3 SEISMO-Lab in Practice

Based on the key principles above the project team has designed a detailed implementation scheme that is focusing on the transformation of the school network to a network of Research and Innovation Hubs in educational seismology. This will be realized through the operation of the Competence Labs framework discussed in the previous chapters. These hubs will be established in different regions of the participating countries, with the aim of implementing the SEISMO-Lab Demonstrators. This initiative will serve as a basis for future expansion to numerous schools across Europe. The specific school hubs will operate and organize activities on at least four levels:

- They will design, host, and support actions in which students and teachers from schools will carry out research activities (projects) based on recording seismic vibrations using the low-cost seismographs and analyzing the data. These actions, guided by the scientific team of the project, will cover a wide range of thematic areas, including geometric and mathematical problems (finding the epicenter of the studied earthquake), geological issues (distinguishing tectonic and volcanic earthquakes, Earth tomography), technological constructions and laws of physics (designing and building seismographs using pendulums and electromagnetic principles), computational thinking and coding (developing early warning applications in Scratch and Python). The work of the students could be published in an Students Scientific Journal (for example in the Open Schools Journal for Open Science, https://ejournals.epublishing.ekt.gr/index.php/openschoolsjournal) that accepts articles from students describing their projects and results. This way, students will gain an understanding of the entire scientific process: experiment design, data collection and analysis, and publication of results in the student scientific community.

Figure 5.3. *The Open Schools Journal for Open Science is the first European peer review scientific journal which accepts original papers written by school age students from Primary to Secondary schools across Europe under the mentoring of their Teachers on all aspects of Science, Engineering and Technology. Students and Teachers via school projects produce scientific data that are invited to be published in this journal. The Journal publishes articles on a regular basis. Publication is free of charge and the Journal carries articles in various languages.*

- They will support collaborative actions among the school units of the SEISMO-Lab network (e.g., calculating the speed of seismic waves, identifying the epicenter accurately, and finding coincidences between different stations). This promotes the simulation of the research methodology, based on the collection of qualitative data, sharing, and systematic collaboration among scientists for data analysis. The project Demonstrators will encourage collaboration among the hubs to achieve common research goals while helping students understand the importance of properly functioning seismographs to provide accurate data. This is expected to introduce students to the principles of Responsible Research.

- They will serve as training and development centers for other teachers and provide information to the local community. Through training, teachers will design new scenarios and actions that other educators can adapt to their own needs. Seminars and training sessions will be conducted, and the development of virtual learning communities through the project's online platform will be supported. The hubs will not only support teachers and other schools in their region but also educational communities nationwide through the internet (e.g., the Ellinogermaniki Agogi is certified by the Ministry of Education as a Support Center for Teachers Training in East Attica).

- They will be central support points for national-level competitions and actions (e.g., competitions for building seismographs, smart algorithms for early earthquake warning, hackathons among students or students).

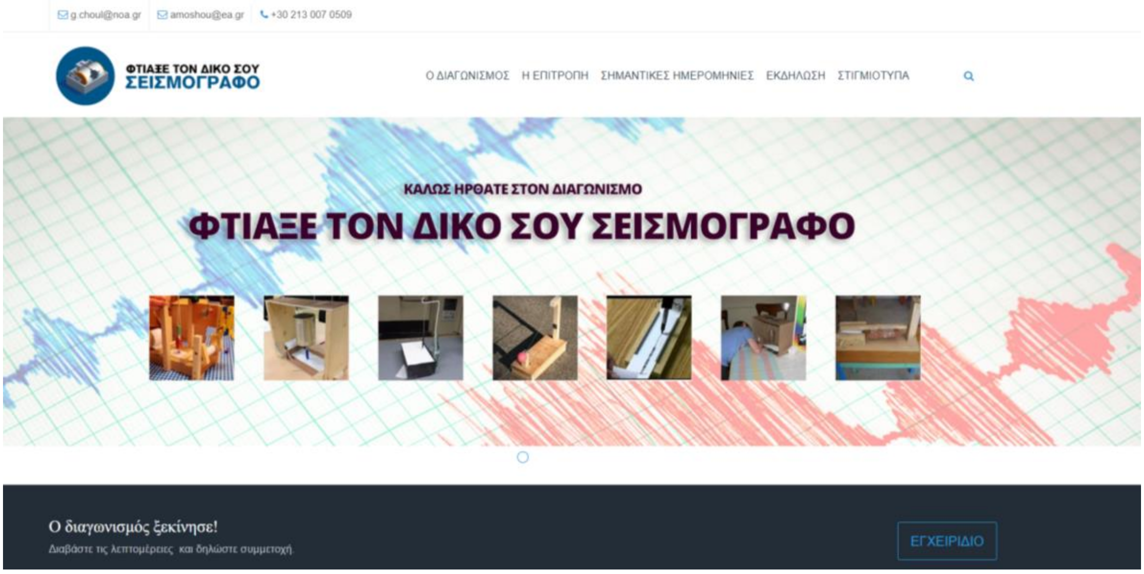


Figure 5.4. *The SEISMO-Lab project will engage numerous schools to participate in national and international challenges and contests in the field of seismology. An example of such activities is the "Build your own Seismometer" Contest that is organized annually for Greek Schools from NOA and EA in cooperation with the Greek eTwinning Support service.*

To implement these actions, the project will:

- Develop a series of Demonstrators that will allow for the successful integration of Responsible Research and Innovation into the teaching of science with focus on educational seismology. The Demonstrators will be based on innovative pedagogical approaches (e.g., inquiry learning, project-based) along with resource-based methods to engage students in scientific research. The SEISMO-Lab project is not limited to that. By enabling students to experience the role of a responsible citizen, it transforms their school into a hub of information for the local community on the phenomenon of earthquakes. These actions aim to strengthen the scientific potential of local communities regarding information and awareness of the earthquake phenomenon.

- Design an interactive online platform (PR3) that functions as a virtual hub for innovation and training for students, educators, and the public. The project offers the possibility to use the data collected by the school seismographs of the network, in real time, by all school and educational communities (e.g., students) involved. Users can select seismic events (in time and location) and download their records for analysis at different network stations. In addition to educational materials for teachers (lesson plans, suggested activities, etc.), the platform will provide support and management material for the educational tool targeting the user (student or educator).

6 The SEISMO-Lab Educational Scenarios Templates

SEISMO-Lab Framework aims to promote deeper learning in STEAM by demonstrating how real science works. In this chapter we describe what is expected to happen in a STEAM classroom and the most effective instructional methods to establish a culture of inquiry and deeper learning in the classroom.

6.1 Deeper Learning in STEAM

The concept of deeper learning has been used both to describe a set of competencies or educational objectives and to characterise a way of learning (or a process) that promotes these competencies. The William and Flora Hewlett Foundation defined deeper learning as (William and Flora Hewlett Foundation, 2013, p. 1)[19]:

"a set of competencies learners must master in order to develop a keen understanding of academic content and apply their knowledge to problems in the classroom and on the job".

According to this definition, deeper learning is the outcome of developing six interconnected competencies that are prerequisites for success not only in school, but also at university, career, and civic life (William and Flora Hewlett Foundation, 2013; William and Flora Hewlett Foundation, 2016[20]):

- Mastery of core academic content
- Critical thinking and complex problem-solving skills
- Collaboration skills
- Effective communication skills
- An understanding of how to learn
- Development of academic mindsets

Deeper learning is a pedagogical approach that effectively conveys essential educational content to students through inventive methods, empowering them to not only absorb knowledge but also put it into practical use. At the heart of this educational journey is a strong emphasis on building a solid foundation of core subject matter.

Authentic deeper learning goes beyond mere knowledge acquisition. It involves the development of competencies that equip high school graduates for success in higher education and vocational pursuits. This, in turn, allows them to effectively apply their acquired knowledge in both personal and professional contexts. Substantiating this approach is empirical evidence, which demonstrates that learning environments fostering deeper understanding positively influence not only students' academic accomplishments but also their socio-emotional well-being (AIR, 2015)[21].

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[19] The William and Flora Hewlett Foundation. (2013). Deeper learning defined. Retrieved 25.9.2022 from http://www.hewlett.org/library/hewlett-foundation-publication/deeper-learning-defined

[20] The William and Flora Hewlett Foundation. (2016). What is Deeper Learning? Retrieved 30.9.2022, from http://www.hewlett.org/programs/education/deeper-learning/what-deeper-learning

[21] AIR (2015). "DEEPER LEARNING Improving Student Outcomes for College, Career, and Civic Life". Accessed on 1.04.2019 at http://www.air.org/resource/deeper-learning-improving-student-outcomes-college-career-andcivic-life

STEAM, going beyond being a mere acronym, represents a transdisciplinary educational approach that combines various domains to foster integrated learning. In contrast to STEM, which has found its place in national strategies and educational reforms, the adoption and establishment of a robust policy framework for the STEAM approach remain largely unexplored in many countries.

Simultaneously, an increasing number of companies and research institutions are embracing the concept of having artists as part of their teams, recognizing the value of their creativity and unbiased problem-solving skills. This isn't a new concept and is demonstrated in an instructive book that promotes the integration of STEAM into our daily lives. The aim of SEISMO-Lab Demonstrators is to showcase numerous instances where the convergence of arts, along with ethical and aesthetic insights, plays a vital role in driving innovation and modernization. It offers fresh perspectives on complex issues, such as the expressive phenomena of our planet, like the sonorous manifestations of Earth movements due to earthquakes (as depicted in Figure 5.2 in the preceding chapter).

The interconnectedness of science and arts has been recognized for an extended period, with prominent scientists harnessing the arts not only for communication but also to enhance their comprehension of various phenomena. It is widely accepted that science can substantially benefit from the creative and adaptable facets that the arts provide. Although STEAM is a subject of discussion and adoption in several educational systems, its practical implementation as a genuinely interdisciplinary experience remains a challenge. Generally, we encounter instances where the integration of the arts with STEM initiatives occurs, but the allocation of commensurate significance to the arts remains limited.

6.2 The Deeper Learning classroom

This section aims to provide an idea of what deeper learning SEISMO-Lab classroom looks like. To make clear the differences and the necessary changes, we are setting a set of questions teachers can ask to figure out what students are learning. One can use the questions as cues to figure out where the classroom changes are just interior design and where they are allowing students to master content in different and more long-lasting ways.

In contrast to a conventional classroom setting, the primary objective is for students to acquire at least an equivalent level of subject matter expertise but through more engaging methodologies. To address challenging questions, teachers often collaborate across disciplinary boundaries, fostering partnerships between mathematics and English instructors, graphic design and geography teachers, or science and art teachers, for example. Notable characteristics of a deeper learning classroom include:

- Substantial peer-to-peer dialogues concerning complex issues that defy binary responses, necessitating analytical thinking.
- Interdisciplinary themes that may extend beyond the typical class durations.
- Collaborative group work, with students formulating questions and compelling one another to defend their viewpoints.

According to PISA (2018)[22], educational systems should prioritize the mastery of processes, the comprehension of concepts, and the capacity to adapt to diverse scenarios over the mere possession of specific knowledge. Hence, educational systems need to reorient their focus from content to skills, investing more in the cultivation of students' essential competencies and abilities. Implementing interdisciplinary learning and adopting a STEM approach within educational systems can significantly enhance the quality of learning episodes, emphasizing skills, deepening conceptual comprehension, and situating concepts within their real-world contexts.

This approach allows students to explore mathematics and science within a personalized context, fostering the development of critical thinking skills applicable to various aspects of both their academic and professional lives. Engineering serves as the method students employ for discovery, exploration, and problem-solving, while the technology component enhances understanding across the other three facets of STEM education. Such applications allow for “more comprehensive exploration of STEM subjects in a practical and detailed manner” (Kennedy, 2014)[23].

As illustrated above, integrating activities that interlace technology and engineering with science and mathematics can effectively align with the findings articulated by Sawyer, thereby assisting students in the acquisition of 21st-century skills, enabling the immediate application of their acquired knowledge within a meaningful context closely linked to their lives and contemporary societal requirements. This approach is greatly encouraged within the SEISMO-Lab framework, which ultimately encourages students to envision novel possibilities in STEAM education.

This section presents an illustrative representation of a future where students can explore distant cultures and epochs as if they were present. It outlines the deeper learning classroom and delineates the activities expected within such an environment. Within the SEISMO-Lab project framework, these images have informed the development of educational activities.

Figure 6.1 (source: deeperlearning4all.org) symbolizes the overarching concept of the Deeper Learning Classroom, catalyzing the transformation of conventional classrooms into innovative environments conducive to scientific exploration and the cultivation of critical skills for all students. The figure presents a glimpse of the SEISMO-Lab classroom that builds on the key aspects of formal education enriched with unique real-science experiences that could facilitate the development of key competencies. The process of transforming the traditional school classroom into a deeper learning environment is not simple and requires a whole school approach as was discussed in the previous chapters of this deliverable. Still, in the framework of the project, we have the chance to demonstrate how the educational community could be prepared for such critical interventions. The SEISMO-Lab Competence Labs offer a unique opportunity that holds great potential to transform science education toward a more engaging environment based on an innovative curriculum, enriched with

[22] PISA (2018) https://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf

[23] Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM education. Science Education International, 25(3), 246-258.

meaningful projects related to local challenges, passion-led teaching and learning, and pervasive opportunities for research and constructive challenge.

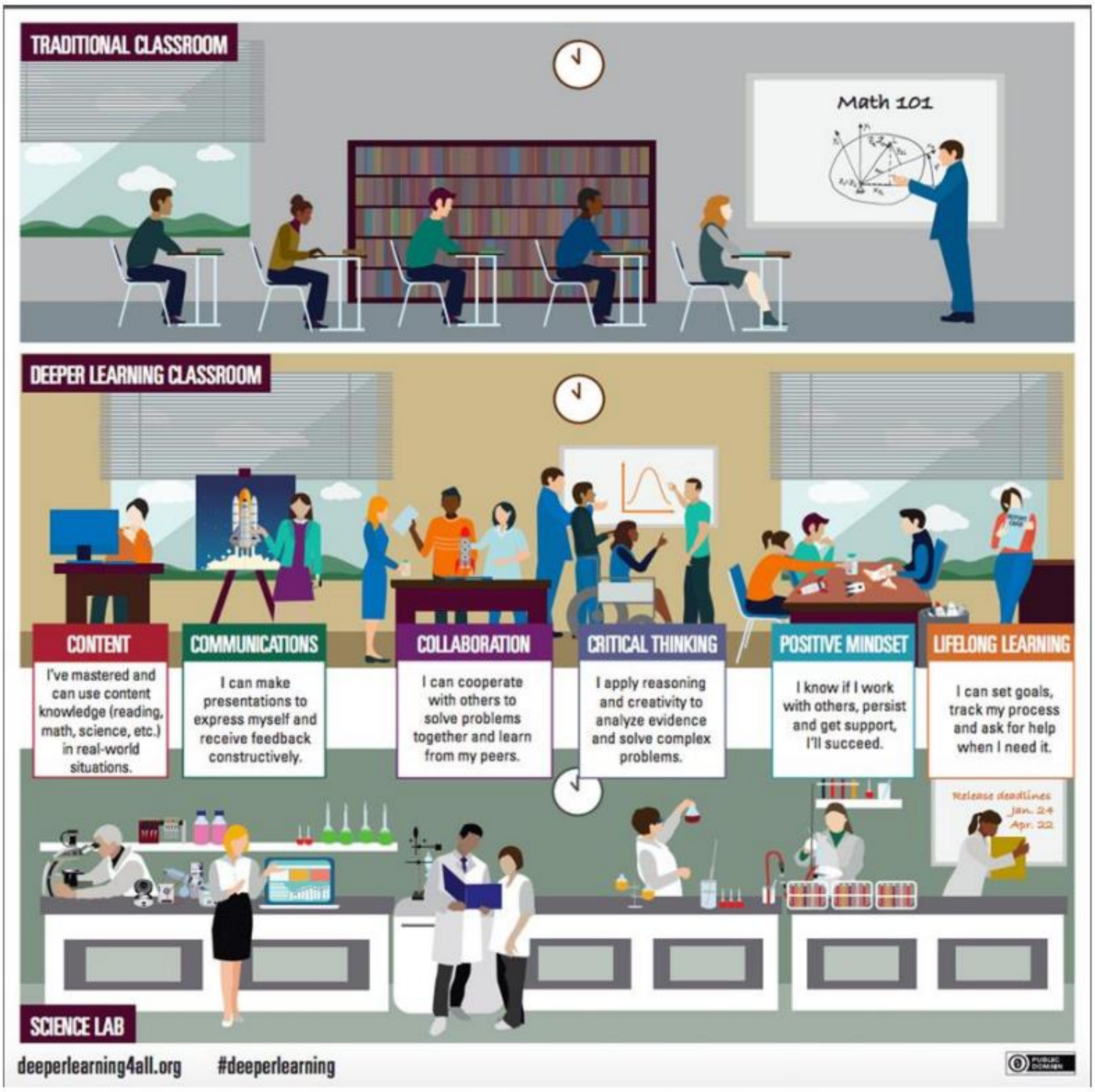

Figure 6.1: *The Deeper Learning Classroom facilitates that transformation of the traditional science classroom to a living laboratory that simulates the research work and introduces students to the scientific exploration. In such an environment, supported with the necessary resources, students are developing key skills like creative problem-solving competences, critical thinking, collaborative spirit and academic mindset while they are getting familiarised with a culture of sharing. For a teacher to be a coach of learning, he or she must fluidly shift among a range of roles, including learning designer; facilitator; networker; and an advisor who coaches, counsels, mentors, and tutors depending on what is most needed to promote student learning (deeperlearning4all.org).*

To achieve that we introduce a range of instructional models and approaches poised to facilitate the realization of the Deeper Learning classroom. The portfolio of proposed models encompasses various forms of inquiry-based learning, offering immense potential to reform contemporary science education classrooms. These models are elucidated in-depth, affording educators the opportunity to apply and tailor them to their own educational activities. We provide detailed descriptions of the inquiry-based model, the Learning Cycle, the project-based model, the 5E model, and the Guided Research Model, each of which comprises a series of sub-activities designed to foster the development of key student competencies.

6.3 Inquiry-Based Teaching

6.3.1 Description of the Educational Scenario Template in Narrative Format

Table 6.1: *Description of the Educational Scenario Template*

Describing an Educational Scenario Template		
1.	Title of the Educational Scenario Template	Inquiry-Based Teaching
2.	Educational Problem	Main problems a) theoretical and abstract teaching b) textbook-based instruction c) no demonstration infrastructure available d) student misconceptions
3.	Educational Scenario Template Objectives	**Knowledge** Learners should know and understand specific concepts and the analogies between them. **Skills** Students should be able to: • Explore the research procedures themselves • Perform research efforts that are taking place as a structured discovery within the frame of organised teaching • Design and conduct scientific investigations • Formulate and revise scientific explanations and models using logic and evidence • Recognise and analyse alternative explanations and models. **Attitudes** Students should be able to: • Acquire an appreciation for basic Science Education matters through exposure to similar topics • Communicate and defend a scientific argument
4.	Characteristics and Needs of Students	**Cognitive** Students have less than average knowledge level of mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of students have a significant interest in science (both boys and girls). A small number of them (about 15%) will follow careers in science (Sjøberg & Schreiner 2005, PISA 2006). **Physiological** The average age of students is 15-16 years. **Needs** Students should: • develop abilities necessary to do scientific inquiry • develop understandings about scientific inquiry • identify questions and concepts that guide scientific investigations • design and conduct scientific investigations • use technology and mathematics to improve investigations and communications • formulate and revise scientific explanations and models using logic and evidence • recognise and analyse alternative explanations and models • communicate and defend a scientific argument

Describing an Educational Scenario Template	
5. Educational Approach of the Educational Scenario Template (a) Description of the Educational Approach rationale (b) Parameters that guarantee the implementation of the Educational Approach	(a) From a pedagogical perspective, **Inquiry-Based Learning** is often contrasted with more traditional expository methods and reflects the constructivist model of learning, often referred to as active learning, so strongly held among science educators today. According to constructivist models, learning is the result of ongoing changes in our mental frameworks as we attempt to make meaning out of our experiences (Osborne et al, 2003). In classrooms where students are encouraged to make meaning, they are generally involved in "developing and restructuring [their] knowledge schemes through experiences with phenomena, through exploratory talk and teacher intervention" (Newton et al, 1999). However, we use *inquiry-based learning* in a more specific manner, referring to a specific teaching model: an iterative process of (1) question eliciting activities, (2) active investigation by students, (3) creation, these are (4) discussed already at early stages of the process, leading to (5) reflection about knowledge and the learning process, which in turn leads to new and refined questions (1) and the process goes on for another cycle. (b) Students are likely to begin to understand the natural world if they work directly with natural phenomena, using their senses to observe and using instruments to extend the power of their senses. Moreover, students must have access to PCs that are connected to the Internet.
6. Learning Activities:	
Phase 1: Question Eliciting Activities	**Exhibit curiosity** Teacher tries to attract the students' attention by presenting/ showing to them appropriate material. **Define questions from current knowledge** Students are engaged by scientifically oriented questions imposed by the teacher.
Phase 2: Active Investigation	**Propose preliminary explanations or hypotheses** Students propose some possible explanations to the questions that emerged from the previous activity. The teacher identifies possible misconceptions. **Plan and conduct simple investigation** Students give priority to evidence, which allows them to develop explanations that address scientifically oriented questions. Teacher facilitates the process.
Phase 3: Creation	**Gather evidence from observation** Teacher divides students in groups. Each group of students formulates and evaluates explanations from evidence to address scientifically oriented questions.
Phase 4: Discussion	**Explanation based on evidence** Teacher gives the correct explanation for the specific research topic. **Consider other explanations** Each group of students evaluates its explanations in light of alternative explanations, particularly those reflecting scientific understanding.

Describing an Educational Scenario Template	
Phase 5: Reflection	**Communicate explanation** Each group of students produces a report with its findings, presents and justifies its proposed explanations to other groups and the teacher.
7. Participating Roles:	**Students** • Perform scientific prediction • Recording observations • Perform prediction compared to results • Develop experimental models **Group Participant** • Use or evaluate a technique • Use science to explain **Teacher** • Presents ideas and evidence in science • Asks questions • Identifies misconceptions • Applies scientific methods • Develops experimental models • Provides historical and contemporary examples
8. Tools, Services and Resources	**Tools:** *Hardware* • Computer • Projector *Software* • Text, image, audio or video viewer • Database • VLE **Resources:** • Figure, graph, slide, problem statement, simulation, experiment, table, self-assessment, exercise, questionnaire, exam.

6.3.2 Graphical Representation of the Flow of Learning Activities

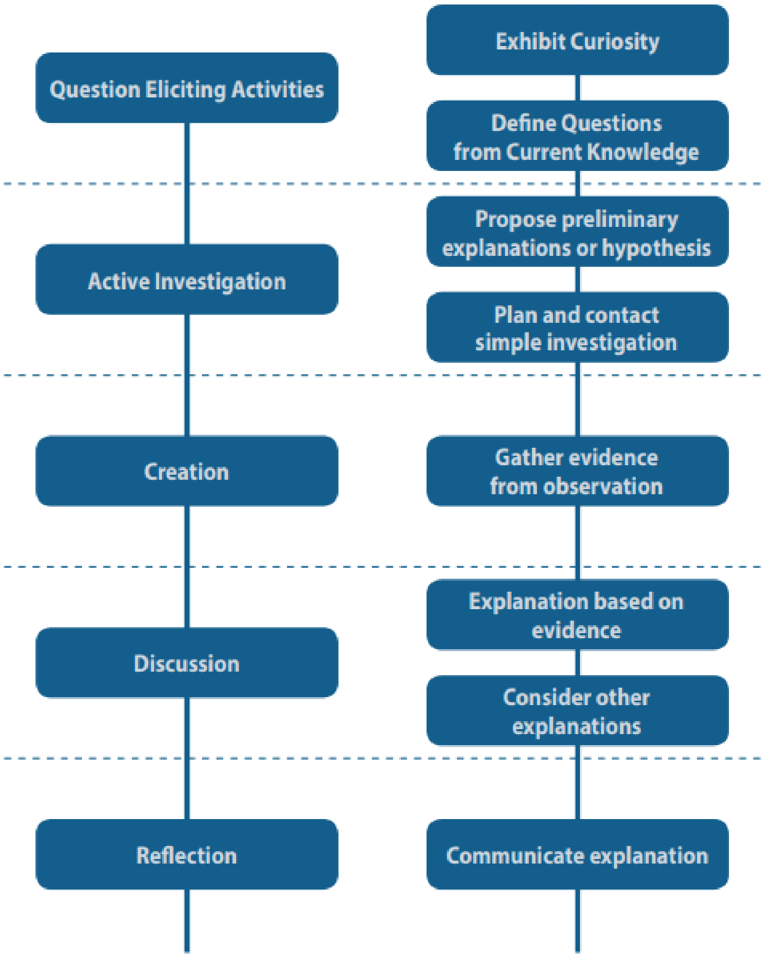

Figure 6.2: *Flow of Learning Activities for Inquiry-Based Teaching*

6.4 The Learning Cycle

6.4.1 Description of the Educational Scenario Template in Narrative Format

Table 6.7: *Description of the Educational Scenario Template*

Describing an Educational Scenario Template	
1. Title of the Educational Scenario Template	The Learning Cycle
2. Educational Problem	Main problems: e) theoretical and abstract teaching f) textbook-based instruction g) no demonstration infrastructure available h) student misconceptions
3. Educational Scenario Template Objectives	**Knowledge** Learners should know and understand specific concepts and the analogies between them. **Skills** Students should be able to: • Explore the research procedures themselves • Perform research efforts that are taking place as a structured discovery within the frame of organised teaching • Generalise or transfer ideas to other examples used as illustrations of the central concept • Apply previous knowledge **Attitudes** Learners should be able to: • Acquire an appreciation for basic Science Education matters through exposure to similar topics • Develop interests, and initiate and maintain a curiosity toward the materials.
4. Characteristics and Needs of Learners	**Cognitive** Students have less than average knowledge level of mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of students have a significant interest in science (both boys and girls). A small number of them (about 15%) will follow careers in science (Sjøberg & Schreiner 2005; PISA, 2006). **Physiological** The average age of students is 15 years. **Needs** Learners need more participatory schemes of instruction. Learners have to be involved in the process and act as members of a team.

Describing an Educational Scenario Template	
5. Educational Approach of the Educational Scenario Template (a) Description of the Educational Approach rationale (b) Parameters that guarantee the implementation of the Educational Approach	(a) The learning cycle originated in the 1960s with the work of Robert Karplus and his colleagues. Originally, the learning cycle was based on the theoretical insights of Piaget, but it is also consistent with other theories of learning, such as those developed by Ausubel (Karplus, 1980). Anton Lawson (1988) has made important connections between research on student misconceptions and use of the learning cycle. Lawson suggests that use of the learning cycle provides opportunities for students to reveal prior knowledge (particularly, their misconceptions) and opportunities to argue and debate their ideas. This process can result in cognitive disequilibrium and the possibility of developing higher levels of reasoning. Originally there were three phases to the learning cycle: Exploration, Invention, and Discovery. Later, these terms were modified to Exploration, Concept Introduction, and Concept Application. Although other terms have been used for the three original phases, the goals and pedagogy of the phases have remained similar. During the first, or Exploration, phase of the learning cycle, students learn through their involvement and actions. New materials, ideas, and relationships are introduced with minimal teacher guidance. The goal is to allow students to apply previous knowledge, develop interests, and initiate and maintain a curiosity toward the materials. During the exploration, teachers can also assess students' understanding and background relative to the lesson's objectives. Concept Introduction is the next phase. Various teaching strategies can be used to introduce the concept. For example, a demonstration, DVD, CD-ROM, textbook, or lecture can be used. This phase should relate directly to the initial exploration and clarify concepts central to the lesson. Although the exploration was minimally teacher directed, this phase tends to be more teacher guided. In the next phase, Concept Application, students apply the newly learned concepts to other examples. The teaching goal is to have students generalize or transfer ideas to other examples used as illustrations of the central concept. For some students, self-regulation, equilibration, and mental reorganization of concepts may take time. An excellent introduction to and science teaching examples of the learning cycle have been developed by Howard Birnie (1982) and Karplus and colleagues (1977). (b) The materials that will be used should be carefully structured so involvement with them cannot help but engage concepts and ideas fundamental to the lesson's objectives. Having several activities where a concept is applied can provide the valuable time needed for learning.

Describing an Educational Scenario Template	
6. Learning Activities:	
Phase 1: Concept Exploration	**Observation** Students observe objects, events, or situations. Student experiences can occur in the classroom, laboratory, or field. **Exploration** Students explore the objects, events, or situations. During this experience, students may establish relationships, observe patterns, identify variables, and question events. Moreover students may have questions or experiences that motivate them to study what they have observed.
Phase 2: Concept Introduction	**Concept Introduction** The teacher directs student attention to specific aspects of the exploration experience. Initially, the lesson should be clearly based on student explorations. In this phase, the teacher presents to students the concepts in a simple, clear, and direct manner.
Phase 3: Concept Application	**Generalisation of the concept** Students extend the concepts in new and different situations. Several different activities will facilitate generalization of the concept by the students. Teacher encourages students to identify patterns, discover relationships among variables, and reason through new problems.
7. Participating Roles:	**Students** • Perform scientific prediction • Recording observations • Perform prediction compared to results • Develop experimental models • Use or evaluate a technique • Use science to explain **Teacher** • Presents ideas and evidence in science • Asks questions • Identifies misconceptions • Applies scientific methods • Develops experimental models • Provides historical and contemporary examples
8. Tools, Services and Resources	**Tools:** *Hardware* • Computer • Projector *Software* • Text, image, audio or video viewer • Database • VLE **Resources:** Figure, graph, slide, problem statement, simulation, experiment, table, self-assessment, exercise, questionnaire, exam.

6.4.2 Graphical Representation of the Flow of Learning Activities

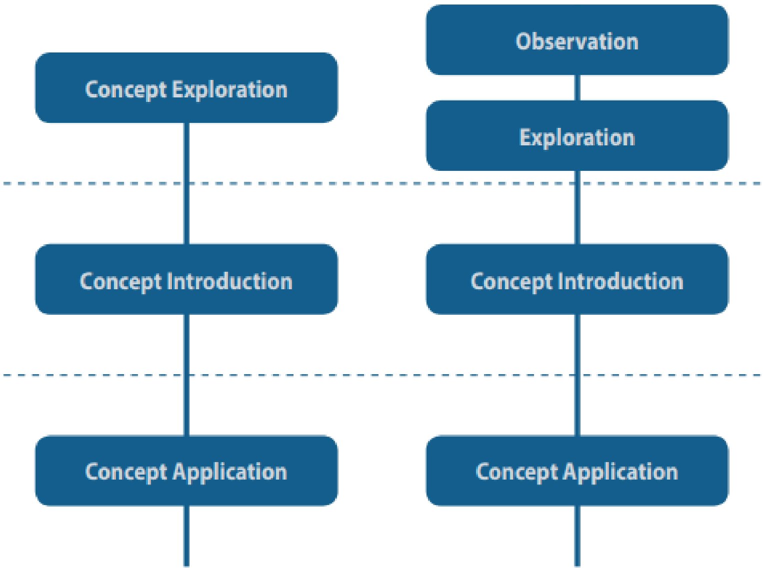

Figure 6.3: *Flow of Learning Activities for The Learning Cycle*

6.5 The 5E Instructional Model

6.5.1 Description of the Educational Scenario Template in Narrative Format

Table 6.11: *Description of the Educational Scenario Template*

Describing an Educational Scenario Template	
1. Title of the Educational Scenario Template	The 5E Instructional Model
2. Educational Problem	Main problems: a) lack of student engagement b) theoretical and abstract teaching c) textbook-based instruction d) no demonstration infrastructure available e) student misconceptions f) lack of embedded assessment methods
3. Educational Scenario Template Objectives	**Knowledge** Students should be able to know and understand specific concepts and the analogies between them. **Skills** Students should be able to: • Explore the research procedures themselves • Perform research efforts that are taking place as a structured discovery within the frame of organised teaching • Generalise or transfer ideas to other examples used as illustrations of the central concept • Apply previous knowledge **Attitudes** Learners should be able to: • Acquire an appreciation for basic Science Education matters through exposure to similar topics • Develop interests, and initiate and maintain a curiosity toward the materials
4. Characteristics and Needs of Learners	**Cognitive** Students have less than average knowledge level of mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of students have a significant interest in science (both boys and girls). A small number of them (about 15%) will follow careers in science (Sjøberg & Schreiner 2005; PISA, 2006). **Physiological** The average age of students is 15 years. **Needs** Learners need more participatory schemes of instruction. Learners have to be involved in the process and act as members of a team.

Describing an Educational Scenario Template	
5. Educational Approach of the Educational Scenario Template (a) Description of the Educational Approach rationale (b) Parameters that guarantee the implementation of the Educational Approach	(a) The 5E instructional model (Bybee 1997, BSCS 2006, Bybee et al., 2008) is a general instructional model that incorporates many elements of other models. An important instructional aspect of the 5E model is that students must be dissatisfied with the current conception, and the new conception must be intelligible, plausible, and fruitful. A science teacher introduces a new concept, and students are unable to reconcile the new concept with current knowledge and experience. The teacher then provides experiences and information that helps students make sense of the new conception. As students consider and try to incorporate the new conception, they must see that a world in which the conception is true is generally reconcilable with their worldview. Finally, students must see that there are instances where there is good reason to supply the new conception—namely, it works and it helps explain things. The following are general strategies based on the constructivist view of learning: • Recognise students' current conceptions of objects, events, or phenomena. • Present situations slightly beyond the students' current conceptual understanding. One could also present students with problems, situation conflicts, paradoxes, and puzzles. • Choose problems and situations that are challenging but achievable. • Have students present their explanations (concepts) to other students. • When students are struggling with inadequate explanations (misconceptions), first help them by accepting their explanations; second, by suggesting other explanations of the same phenomena or activities designed to provide insights; and third, by allowing them time to reconstruct their explanations. Students redefine, reorganise, elaborate, and change their initial concepts through interactions among the environment, classroom activities and experiences, and other individuals. Individual learners interpret objects and phenomena and internalise the interpretation in terms of their current concepts similar to the experiences being presented or encountered. In other words, changing and improving conceptions often require challenging the current conceptions and showing them to be inadequate. From a science teacher's point of view, the instructional and psychological problem is to avoid leaving students with an overall sense of inadequacy. If a current conception is challenged, there must be opportunity, in the form of time and experiences, to reconstruct a more adequate conception than the original. In short, the students' construction of knowledge can be assisted by using sequences of lessons designed to challenge current concepts and provide opportunities for reconstruction to occur. The 5E instructional model has five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation. Each phase has a specific function and is intended to contribute to the learning process. (b) Regardless of the specific instructional model, helping students to develop more adequate scientific concepts is an important goal of science teaching. It is also a difficult task. An assumption of the 5E model is that using sequences of lessons designed to facilitate the process described above will assist in students' construction of knowledge. Another assumption is that concrete experiences and computer-assisted activities will assist in the process of constructing knowledge.

Describing an Educational Scenario Template	
6. Learning Activities:	
Phase 1: Engagement	**Minds-on, Hands-on Experience** Teacher engages students in the learning task. Students, mentally focus on a problem, situation, or event while the teacher helps them to make connections between past and present learning experiences. **Organise Student's Thinking** Teacher organises students' thinking toward the learning outcomes of current activities. These activities make connections to past and future activities.
Phase 2: Exploration	**Exploration – Observation** Students are given time to explore objects, the phenomenon, events, or situations. As a result of their mental and physical involvement in the exploration activity, students establish relationships, observe patterns, identify variables, and question events.
Phase 3: Explanation	**Identification of student knowledge** Teacher directs student attention to specific aspects of the engagement and exploration experiences. Students are asked to give their explanations. Based on the students' explanations, the teacher clearly connects the explanations to experiences in the engagement and exploration phases. **Explaining concepts** Teacher introduces scientific or technological explanations in a direct and formal manner. He/she presents scientific concepts, processes, or skills in a simple, clear, and direct manner, and move on to the next phase.
Phase 4: Elaboration	**Discussion** Students discuss in order to express their understanding of the subject and receive feedback from others and the teacher. **Information seeking** This discussion leads to better defining the task as well as to identify and gather the information that is necessary to complete the task successfully.
Phase 5: Evaluation	**Evaluate concepts, attitudes and skills** Students assess their understandings and abilities while teachers evaluate student progress towards achieving the educational objectives.

Describing an Educational Scenario Template	
7. Participating Roles:	**Students** • Establish an interest in, and develop an approach to, the learning task. • Complete activities directed toward learning outcomes. • Describe their understanding, use their skills, and express their attitudes. • Present and defend their explanations and identify and complete several experiences related to the learning task. • Examine the adequacy of their explanations, behaviours, and attitudes in new situations. **Teacher** • Identifies the learning task. • Facilitates and monitors interaction between students and instructional situations, materials, and/or courseware. • Directs student learning by clarifying misconceptions, providing vocabulary for concepts, giving examples of skills, modifying behaviours, and suggesting further learning experiences. • Provides an occasion for students to cooperate on activities, discuss their current understanding, and demonstrate their skills. • Uses a variety of formal and informal procedures for assessing student understanding.
8. Tools, Services and Resources	**Tools:** *Hardware* • Computer • Projector *Software* • Text, image, audio or video viewer • Database • VLE **Resources:** Problem statement, figure, graph, slide, simulation, experiment, table, self-assessment, exercise, questionnaire, exam

6.5.2 Graphical Representation of the Flow of Learning Activities

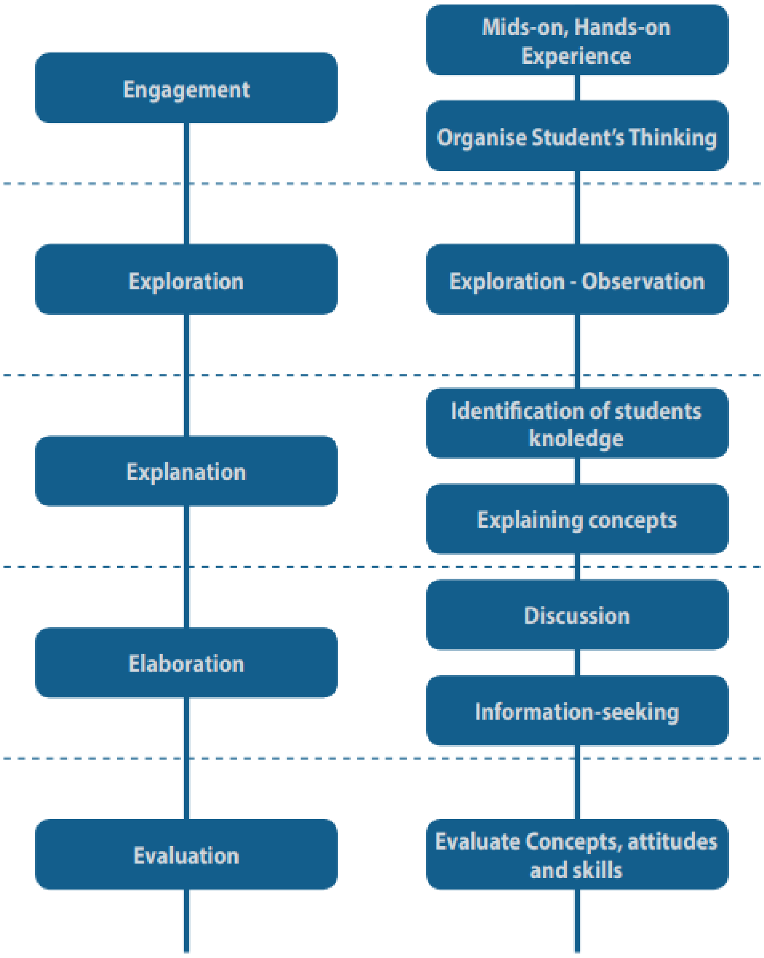

Figure 6.4: *Flow of Learning Activities for the 5E Instructional Model*

6.6 Project-based Learning

6.6.1 Description of the Educational Scenario Template in Narrative Format

Table 6.17: *Description of the Educational Scenario Template*

Describing an Educational Scenario Template		
1.	**Title of the Educational Scenario Template**	Project-based Learning
2.	**Educational Problem**	Students must be engaged in a highly motivating learning experience, which is closely related to the tasks and challenges of the real world. Therefore, emphasis must be given on learning-by-doing, strongly emphasising the activities in an authentic context, i.e. the skills needed in working life, such as being able to work in teams, working in a self-guided manner, and assessing one's own actions (Thomas, 2000).
3.	**Educational Scenario Template Objectives**	**Knowledge** The students should know and understand specific concepts and the analogies between them **Skills** The students should be able to: • Create artefacts • Work in an autonomous and self-guided manner • Present and support what they have learned and share with others • Provide feedback to others • Defend a scientific argument • Recognise and analyse alternative explanations and models • Search and gather data **Attitudes** The students should be able to: • Be interested in Science Education matters • Communicate with others effectively • Appreciate feedback from other learners or teacher
4.	**Characteristics and Needs of Learners**	**Cognitive** The students have a below average knowledge level in mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of students have a significant interest in science (both boys and girls). A small number of them (about 15%) will follow careers in science (Sjøberg & Schreiner 2005, PISA 2006). **Physiological** The average age of students is 15-16 years. **Needs** The learners need to be engaged in tasks that will help them relate science matters with everyday life world.

Describing an Educational Scenario Template		
5.	**Educational Approach of the Educational Scenario Template** (a) Description of the Educational Approach rationale (b) Parameters that guarantee the implementation of the Educational Approach	(a) Project-based learning aims at giving students a highly motivating learning experience, which is closely related to the tasks and challenges of the real world. Project-based learning also supports learning so called "adult skills", which include skills such as working in teams, working in self-guided manner, and assessing one's own actions. Project-based learning is also connected to the idea of attaining transferable skills such as problem solving (Helle et al., 2006). The projects in Project-based learning are challenging and complex tasks that are based on some topics, questions, or problems that are driving the working in projects. Challenging and complex tasks means here that the tasks must be such that they cannot be accomplished successfully without new learning taking place. The projects at hand usually involve elements from various subjects, which make them multidisciplinary and not bound to any particular subject domain. The nature of the tasks has to be such that it involves learners in various kinds of activities that support learning, such as designing, problem-solving, decision-making, and active investigation. In projects, the learners work autonomously and collaboratively in small groups, whereas the teacher assumes the role of a tutor who facilitates the learning process (Henry, 2005). (b) • It must be ensured that there is adequate time to complete the project. • It must be ensured that the students possess the appropriate cognitive background. • The teacher must prepare the topics for the students' projects beforehand. • The teacher, who supports the learning process, should understand his/her role as a facilitator of the learning process. The teacher should not assume an expert role trying to impose his/her knowledge over the topic or directing the learners' activities, but allow learners to do their own learning and make their own decisions in projects. • Projects are central, not peripheral to the curriculum. • Students must have access to PCs that are connected to the Internet.
6.	**Learning Activities:**	
	Phase 1: Definition of the Project Goal	**Organise into Groups** The teacher divides the students into groups and ensures that these groups consist of students with different capacities. **Presentation of the New Question/Problem** The teacher introduces the new question/problem to the students. **Discussion** Students discuss about the new question/problem and contribute opinions and ideas; the teacher provides feedback on the students' opinions.
	Phase 2: Planning the Project	**Discussion among the Group Participants** Students discuss into the context of their groups about the project to be created and the responsibilities of each group member. The teacher interferes to avoid possible misunderstandings.

Describing an Educational Scenario Template	
Phase 3: Doing the Project Work	**Collection of Information** Each group member collects information about the topics related to their project work. The teacher may support students by employing questions to indirectly bring to their attention certain topics that the students might have given little or no attention or he/she may have prepared some material for students that serves as a starting point for further inquiries into those topics. **Synthesis of Information** After the students have collected the information, they synthesise together the collected pieces of information. The teacher can support the synthesis process by asking questions about various concepts and topics and their relations to each other. **Create Project** Students work collaboratively in order to create their project, while the teacher acts as a facilitator to their efforts.
Phase 4: Presentation of the Outcomes	**Project Outcomes Presentation** Each group of students presents the outcomes of the project to others and the teacher. **Discussion/Feedback** Students answer to questions/comments of other students and the teacher.
Phase 5: Assessing the Project Work	**Summative Assessment** The teacher assesses the projects created by student groups
7. Participating Roles:	**Student** • Actively participates in the learning process by expressing his/her ideas, experiences and opinions. **Group Participant** • Works collaboratively in small groups to create their project • Communicates and debates with other group participants • Searches, selects and synthesises information • Creates the final project • Presents the final project • Assesses the other groups **Teacher** • Prepares the project topics for students • Poses questions • Coordinates, mediates, communicates and guides students in order to overcome any difficulties • Evaluates the final project outcomes and the cooperation between the students
8. Tools, Services and Resources	**Tools:** *Hardware* • Computer • Projector *Software* • Text, image, audio or video viewer • Search Engines • Word Processor • VLE **Resources:** problem statement, figure, graph, slide, simulation, experiment, table, self-assessment, exercise, questionnaire, exam

6.6.2 Graphical Representation of the Flow of Learning Activities

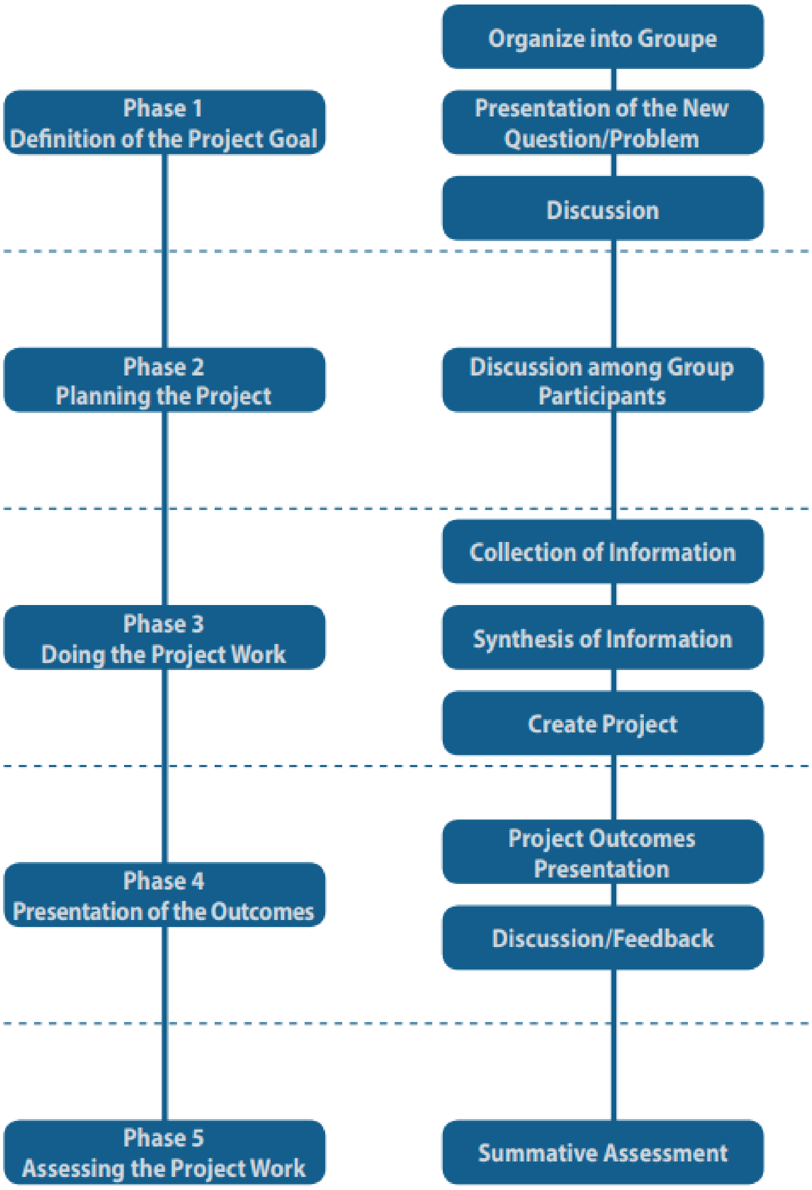

Figure 6.5: *Flow of Learning Activities*

6.7 Guided Research Model

6.7.1 Description of the Educational Scenario Template in Narrative Format

Table 6.23: *Description of the Educational Scenario Template*

Describing an Educational Scenario Template	
1. Title of the Educational Scenario Template	Guided Research Model
2. Educational Problem	Main problems: i) theoretical and abstract teaching j) textbook-based instruction k) no demonstration infrastructure available l) student misconceptions
3. Educational Scenario Template Objectives	**Knowledge** The learners should know and understand specific concepts and the analogies between them. **Skills** The students should be able to: • Explore the research procedures themselves • Perform research efforts that are taking place as a structured discovery within the frame of organised teaching. **Attitudes** The learners should be able to acquire an appreciation for basic Science Education matters through exposure to similar topics
4. Characteristics and Needs of Learners	**Cognitive** The students have less than average knowledge level of mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of students have a significant interest in science (both boys and girls). A small number of them (about 15%) will follow careers in science (Sjøberg & Schreiner 2005; PISA, 2006). **Physiological** The average age of students is 15 years. **Needs** Learners need more participatory schemes of instruction. Learners have to be involved in the process and act as members of a team.
5. Educational Approach of the Educational Scenario Template (a) Description of the Educational Approach rationale (b) Parameters that guarantee the implementation of the Educational Approach	(a) Guided research teaching model of Schmidkunz & Lindemann (1992). The word research in the model description reveals its aim to help students explore the research procedures themselves while the word "guided" emphasises that this research effort will take place as a structured discovery within the frame of organised teaching. This teaching model includes five teaching stages (bringing up the phenomenon to a problem, suggestions for confrontation with the problem, implementation of a suggestion, abstraction of the finding, consolidation). (b) The approach includes "hands on" experimentation, which is very popular for students.

Describing an Educational Scenario Template	
6. Learning Activities:	
Phase 1: Bringing up the phenomenon to a problem	**Presentation** Teacher presents the concept/problem/theory under discussion and alternative theories and ideas. **Discussion** Teacher discusses with students about the concept/problem/ theory and the alternative theories.
Phase 2: Suggestions for confrontation with the problem	**Scientific Prediction** Students are performing hypotheses and predictions and making suggestions for confrontation with the problem.
Phase 3: Implementation of a suggestion	**Setting-Up the Experiment** The students are setting-up the experiment with the support/ guidance of the teacher. **Measuring-Recording** The students are making measurements and are recording their findings.
Phase 4: Abstraction of the finding	**Predictions Compared to Results** The students are making predictions compared to results. The teacher facilitates the process. **Discussion** Discussion of the theoretical issues arising from the experimental activities
Phase 5: Consolidation	**Questions, Exercises and Tasks** The teacher is making questions and assigning exercises and tasks aiming at consolidation of the acquired knowledge
7. Participating Roles:	**Students** • Perform scientific prediction • Recording observations • Perform prediction compared to results • Develop experimental models • Use or evaluate a technique • Use science to explain **Teacher** • Presents ideas and evidence in science • Asks questions • Identifies misconceptions • Applies scientific methods • Develops experimental models • Provides historical and contemporary examples
8. Tools, Services and Resources	**Tools:** *Hardware* • Computer • Projector *Software* • Text, image, audio or video viewer • Database • VLE **Resources:** Figure, graph, slide, problem statement, simulation, experiment, table, self-assessment, exercise, questionnaire, exam.

6.7.2 Graphical Representation of the Flow of Learning Activities

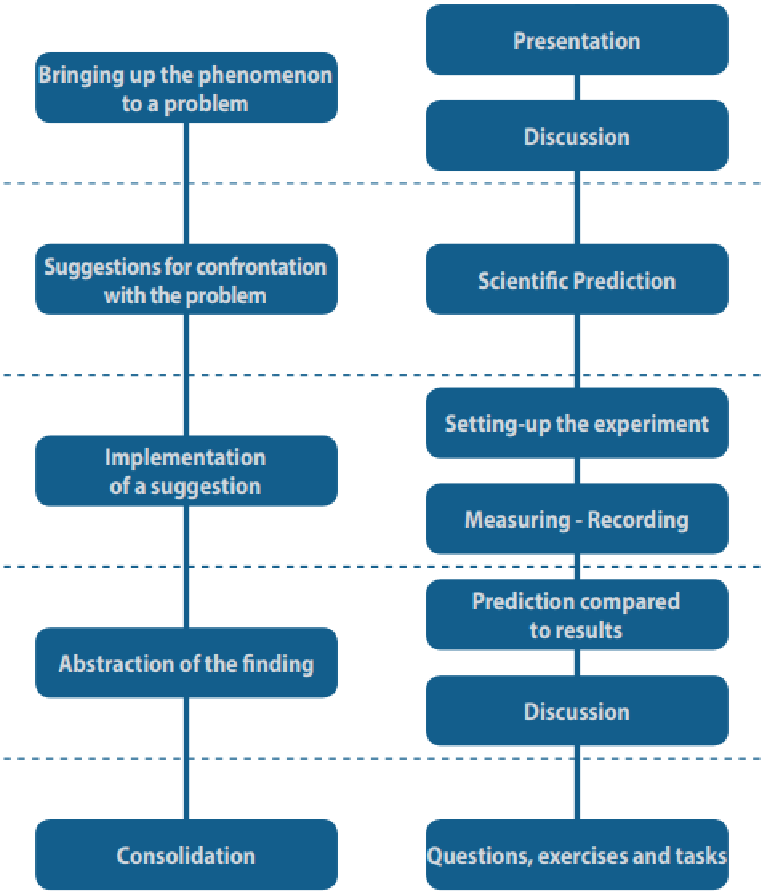

Figure 6.6: *Flow of Learning Activities for Guided Research Model*

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8 Annex

The vocabulary used for the Learning Activities description in common terms, is explained in the following table:

Table A: *Learning Activities description*

Annex		
Dimension	**Type and Value**	**Description**
Type	Communicative: Presenting	Presentation of a specific subject/work
	Communicative: Debating	A structured discussion of opposing points of view
	Information Handling: Analysing	Analysing a concept or a problem
	Productive: Synthesising	Synthesising data into a new whole
	Experiential: Exploring	Students give priority to evidence, which allows them to develop explanations that address scientifically oriented questions.
	Experiential: Experiencing	Performing experiments and observations
Technique	Information Handling: Brainstorming	A problem or idea is defined and all participants make suggestions related to the topic.
	Adaptive: Modelling	Formulate models to explain hypotheses or findings from the observations
	Experiential: Experiment	Designing, Setting up and Performing experiments
	Communicative: Structured Debate	A structured debate based on evidence from observations
	Communicative: Arguing	A verbal dispute
	Productive: Report	Production of a report describing the process and the findings
Interaction	Who: Class-based	In the context of the classroom
	Who: Group-based	In the context of the groups
	Medium: Face-to-Face	Face-to-face interaction of the participating role with others or content
	Medium: Online	Interaction via the use of Internet
	Timing: Synchronous	Synchronous interaction of the participating role with others or content
Roles	Individual Learner	The individual learner
	Group participant	A student participating in a group of students
	Facilitator	The teacher in a role of facilitator of the

Annex		
		learning process
	Presenter	The teacher presents the outcomes of the discussion/debate
Tools/ Services	Hardware: Computer	An electronic, digital device that stores and processes information
	Hardware: Projector	A hardware device that enables an image to be projected onto a flat surface
	Software: Text, image, audio or video viewer	A software tool for displaying text, images, audio or video
	Software: Database	Educational Digital Library (e.g. SNAC Database)
	Software: VLE	Virtual environment which engage users in learning activities (e.g. SNAC Database and SEISMO-Lab platform and space for teachers)
Resources	Problem Statement	Document for defining a problem
	Slide	Hypermedia document
	Figure	A figure is any graphic, text, table or other representation that is unaligned from the main flow of text
	Graph	Pictorial representation of information
	Exercise	Document for practicing a skill or understanding
	Simulation	An application that imitates a physical process or object by causing a computer to respond mathematically to data and changing conditions as though it was the process or object itself
	Experiment	An action or operation undertaken in order to discover something unknown, to test a hypothesis, or establish or illustrate some known truth
	Table	An arrangement of information in columns and lines
	Self assessment	An assessment or evaluation of oneself, one's actions or attitudes by oneself
	Questionnaire	A list of questions by which information is sought from a selected group
	Exam	Document for testing the knowledge or ability of students
	Other	It can be any of the following resources: Figure, graph, slide, simulation,

Annex		
		experiment, table, self-assessment, exercise, questionnaire, exam