Project Result 1

SEISMO-Lab Framework for Establishing STEAM School Competence Labs

Co-funded by the Erasmus+ Programme of the European Union

This project has received funding from the European Union's ERASMUS+ Programme under agreement No 2021-1-EL01-KA220-000032578

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WP/Task	Activity A.1
Title	**SEISMO-Lab Framework for Establishing STEAM School Competence Labs**
Due date	1/7/2022
Submission date	1/11/2022
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 for organising, establishing, and implementing 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, learning cycle. This will engage students in projects that will increase their problem-solving skills, creativity, and promotes a learning-by-doing attitudes. 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. It will provide examples and ideas how seismology, scientific data, and student-centred projects in combination with the collaboration and cooperation with external stakeholders can lead to the development of innovative solutions, products and project that can benefit the whole school community. This approach reinforces the development and application of key skills and competences (beyond scientific), adopted to the local conditions by 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 to help schools establishing and operating an open science labs for its students, teachers and how they can offer the opportunity to all stakeholders in the (school) community to participate actively and responsibly in science-informed decision-making and knowledge based innovation. 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 adopted to the local conditions by employing problem-solving skills, dealing with real seismic and scientific data that they students have acquired themselves, handling and studying situations and participating in meaningful and motivating science inquiry activities on earthquake disaster prevention and mitigation. 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 the school settings. It will offer an outline of how any SEISMO-Lab school can embark on the process of project-based teaching & 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 students' performance - Raises the profile of each school that becomes part of the network, encouraging making them an active part in international activities
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Reviewer(s)	Thalia Tsaknia
Dissemination level	☐ internal ☒ public ☐ confidential

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Version	Date	Modified by	Comments
0.1	10.7.22	S. Sotiriou	Table of Contents
0.2	30.7.22	S. Sotiriou	Effective Educational Approaches (Chapter 6)
0.3	30.9.22	S. Sotiriou	Chapters 2 – 5: Deeper Learning Framework and Open Schooling
0.4	30.10.22	S. Sotiriou	Final Draft
FINAL	1.11.22	S. Sotiriou	Final

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 Earth science concepts while promoting skills and competences 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, 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. e) 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. f) Expand the network of school seismometer in different EU countries.

This Project Result (PR) describes the design of **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). The cooperation with the research (NOA and NIEP) and the 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 (Month 1-Month 3). The task explored what has already been put into educational practice in the field of open schooling, but most importantly, it highlighted the portrayal of the current situation that teachers and students have to deal with that has evidently outlined new necessities for the educational community. The Open Schooling approach supports the uptake of innovative practices (combining the strengths of formal and informal science learning) in school communities. It describes the full cycle of the school transformation, that starts with the Change Agents who are becoming Inspiring Leaders of the school community. The SEISMO-Lab online platform and space for teachers will offer open, interoperable, and personalised solutions meeting the local needs and will support school leaders to introduce a new model for cooperation with external stakeholders in their school organisation. This task has also provided concrete actions to recommend strategies to support a large community of schools to develop their own educational pathways towards the development of an open schooling culture. It is within this context, that the SEISMO-Lab project aims to take forward the agenda of practitioner-led innovation at a European level. For a culture of open schooling and transformative innovation to flourish, it needs to be allied with, or developed from, challenges or ideas that correspond to the core needs, objectives and values of

a school, its community and the people within it. When the initiative and drive come from within a school itself, external support is recast as an aid to innovation and the innovation is supported by the momentum of the organisation. To foster such an innovative approach, schools need to become sustainable educational ecosystems encapsulating a wide range of co-existing actors and element. This work is presented in Chapters 1, 2, 3 and 4.

Definition of Implementation Parameters for the integration of the STEAM Competence Labs (Month 1 - Month 5). The aim of this task was not only to describe in detail the proposed pedagogical framework (including all the necessary parameters for the introduction of the project to the school settings), but also the main pedagogical approaches behind it. It provided detailed descriptions on the methods the proposed approach to support project partners to design exemplary educational scenarios (the SEISMO-Lab Demonstrators) and to offer opportunities to the educational community to design their own educational interventions in the framework of the operation of the STEAM Competence Labs. Moreover, this framework outlines the significance of the other backing systems for the students, e.g., to take into consideration additional specifications for teachers and students with disabilities. The definition of the implementation parameters along with the pedagogical design demonstrates a next-generation learning scheme that not only crosscuts the boundaries between formal and informal learning settings but it also recognizes the diversity of personal learning styles and behaviours in different contexts and applications.

The SEISMO-Lab Framework is the result of a dialogic process 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 dialogue was to identify the state-of-the-art and gradually explore and highlight significant opportunities and challenges for innovation enabling a more effective exploitation of the rich but disperse educational content available in the scientific databases and archives of seismological research centres across Europe.

An important tool in the process of consortium-wide consultation are the 'Educational Scenarios Templates', which are presented in Chapter 6. Partners and particularly Content Providers were invited and facilitated to participate in a structured exchange of views about, and experimentation with approaches to, the notion of Educational Scenarios, as well as the practice-oriented and research opportunities arising out of content enrichment techniques. 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 formulation of the present 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 the introduces the key aspects of the project and the purpose of this document).

Chapter 2 describes the SEISMO-Lab Framework. It describes the pedagogical principles for the design of the Educational Scenarios (they are called SEISMO-Lab Demonstrators in the framework of the project) and the expected learning outcomes for the students. It presents their key features and the context of their implementation. Here the expected contribution from the open schooling environment is analyzed in detail. The chapter concludes with the presentation of the project team's vision for the design of Competence Labs that are acting as hubs of innovation in the school community. The chapter highlights that the current organization 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, on how to contextualize knowledge so it is coherent, on how to connect learning to real issues and settings and how to extend learning beyond the school using the unique resources from informal learning settings, on how to inspire students by customizing learning experiences, and 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 consortium, the school heads and the individual teachers, the tailored strategies to support the local schools as they transform themselves into open schooling environments while they are implementing the SEISMO-Lab Framework. The proposed methodologies exemplify the project's overall approach on how we can best support schools in their attempt to evolve, transform and reinvent their structures towards a more open learning environment. In this framework, schools will facilitate open, more effective and efficient co-design, co-creation, and use of educational content (using the database of seismological data and the SEISMO-Lab online platform), tools and services for personalized science learning and teaching that will form the basic ingredients for innovative student projects.

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 has been adopted to support the operation of the SEISMO-Lab Competence Labs in the participating schools.

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1 Introduction

1.1 Rational

Some young people engage easily in school, whereas others struggle to see the 'relevance' of what they are studying. But what is more empowering than creating solutions to real-world issues? When students learn about local and global issues and then try to come up with possible solutions, they become independent thinkers. Real problems provide rich learning opportunities since students must conduct research, hypothesize, create, test, analyze, revise, and synthesize. By operating as Competence Development Labs schools could offer students the opportunity to work actively in science-informed decision-making and knowledge-based innovation. (School) Seismology offers a largely untapped opportunity for capturing a student's innate curiosity about natural phenomena in the world around them; this curiosity can be used as a platform to teach a wealth of cross-curricular key competences, skills and fundamental principles. It is by the knowledge we gain from studying earthquakes that we can start to understand their impact on societies. 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 Earth science concepts while promoting skills and competences 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)[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 which students learn, practice and utilize scientific instruments and methods while they have to communicate the outcomes of their work.

The project approach is based on the Open Schooling concept (EU 2016)[2] that promotes the collaboration of schools with non-formal and informal education providers, enterprises and civil society enhanced to ensure relevant and meaningful engagement of all societal actors with science and increase the uptake of science studies and science-based careers, employability and competitiveness. Individual schools are working with science centers and museums, industries, research institutes, universities in an innovative collaboration towards the introduction of open schooling approaches through a bottom-up approach. By building on the best of current

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

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

practice, such an approach aims to take us beyond the constraints of present structures of schooling toward a shared vision of excellence. Such an innovation programme holds great potential. If we want a powerful and innovative and open culture in schools that is self-sustaining, we must empower system-aware practitioners to create it, whilst avoiding simply creating interesting but isolated pockets of experimentation. Such a partnership fosters expertise, networking, sharing and applying science and technology research findings and that bringing real-life projects to the classroom, supporting the development of 21st-century competencies (creative problem solving, learning by doing, experiential learning, critical thinking and creativity) including projects and activities that simulate the real scientific work.

1.2 Purpose of the document

This Project Result describes a) a cooperation model between schools and informal learning settings (research and science centers), which emboldens the building of the digital education readiness of the educational community and b) a practical framework to bring this new cooperation model in 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 in cases that the physical presence of the 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 forms instructional models of innovative practices by assisting at the same time educators to apply their digital competences during the realization of the proposed educational activities. Current training needs of the target communities, teachers and students, concerning competences regarding the design of educational activities and tools related to the use of scientific databases, analysing real data are also considered and thoroughly explored. Also, schemes that allow science educators and mainly secondary school teachers to identify activities that can be adapted to the described model are investigated to equip them with the skills to face the challenges and to succeed a swift recovery where no students are left behind. To facilitate them as much as possible and targeting at the optimum impact, this PR will also explore the bridging of the proposed educational activities with the curriculum and will propose specific templates that will safeguard this interconnection.

Particular attention is paid on exploring the key features that act as obstacles for certain groups of students during the COVID-19 era to be best organized to act proactively to guarantee their inclusion. The role of the family will also be taken into consideration since they work as a supporting system for the students in distant learning conditions and their lack of certain science knowledge and inadequacy to support their children will result to destructive outcomes. In the same context, the PR explores the prospects of embracing specifications (based on Universal Design for Learning - UDL) for both students and teachers with disabilities ensuring that the project had offered equal opportunities to the educational community that faces such unpredictable challenges. To achieve that the proposed methodology integrates the principles of inclusion in the educational design mechanism. UDL helps to meet this goal by providing a framework for understanding how to create curricula and activities that meet the needs of all students from the start as it provides multiple means of representation, options for language, mathematical expressions, and symbols, options for comprehension, multiple means of action and expression, options for physical action, options for expression and communication, options for executive functions, multiple means of engagement, options for recruiting interest, options for sustaining effort and persistence and options for self-regulation (e.g. facilitate personal coping skills and strategies). Universal design thus becomes integrated into core digital literacy skills that all students develop when interacting with the SEISMO-Lab scenarios and online tools (to be developed in PR2 and PR3).

2 SEISMO-Lab Conceptual Framework in the Open School Context

To understand and value the world we live in, we need to learn about science. We need scientific knowledge and skills to give meaning to information, to value it, to solve problems, to make educated decisions, and to take advantage of opportunities. Without the ability to critically evaluate information, scientific concepts can be misunderstood, and pseudo-scientific reasoning can mislead people. Therefore, we should help students develop the necessary dispositions and become informed citizens capable with others to use science and technology wisely to solve the numerous global problems humans now face. A recent example of this is the misinformation about the COVID-19 pandemic that can be found in popular media as well as the overall attitude of citizens towards the efforts of the scientific community to reduce the spread of the infections.

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

An even larger part of science learning, however, takes place out-of-school. It results from daily activities related to family or leisure. In most cases, it is guided by curiosity or interest and leads to enjoyment. People learn in diverse places, as they grow up, for instance within their families, their communities, through the media, in after-school programmes, in the street, while they travel, and while they visit places like museums and science centres. Sometimes, they learn about the same concepts and phenomena in different learning contexts. As a result, an important question arises: Do these people integrate the same concepts and phenomena which they learn in these different contexts, and if so, how? While some research shows that people create links between different learning contexts[3, 4], most of the literature points to a serious lack of contact between formal and informal learning contexts that are introducing the same concepts and phenomena[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 degree, 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?

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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

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

These developments in out-of-school science education and in formal education seem to offer a unique opportunity to bridge the gap between the two worlds by developing an appropriate catalysing process: A **connected science learning ecosystem** where youth may encounter a wide range of learning experiences and be supported by adults and peers in ways that could lead to future opportunities in personal, academic, professional, and civic realms. This is a vision that requires educators and organizations to think beyond the bounds of their own institutions to consider how collective action at the level of networks can provide opportunities and address inequalities in a way that more isolated efforts cannot. When discussing how youth might thrive in such an ecosystem—and what sort of interventions we can develop to help all youth do so—the idea of pathways[9] has often come up as a useful metaphor that invites us to consider youths' "learning lives" over time and across the many contexts (e.g., home, school, community organizations, science centres and museums, web and social media) where learning may occur. While there are many different ways to productively conceptualize such pathways, we simply invoke pathways as a metaphor for thinking about ways to provide structure to youth experiences – **Learning Paths** –, how they might "connect to" or "build upon" one another and thus allow a young person to pursue goals that require extended engagement or persistence across multiple contexts and learning opportunities. Learning paths take many forms influenced by emerging research and discoveries, changes in the needs and interests of society, and changes in personal interests or opportunities. Some individuals describe their learning path as an upward trajectory, pointed towards a clear goal. Others describe their path as more irregular, resembling steps or, more often, an erratic bumpy line. Learning opportunities are made possible and shaped by the learning ecology that one inhabits.

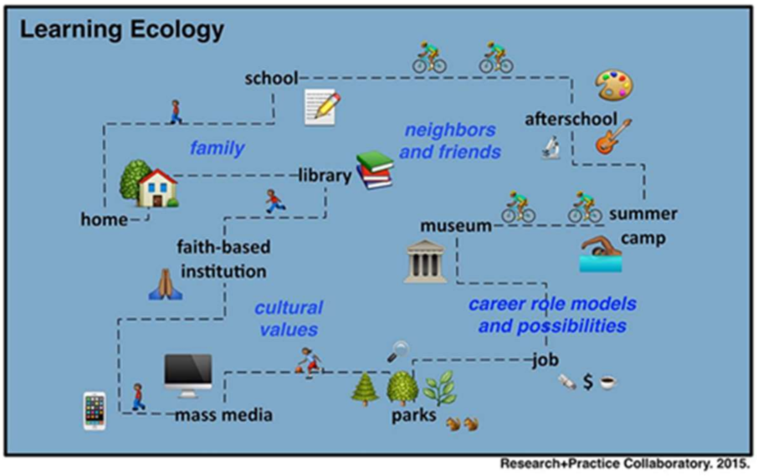

Figure 2.1: *A graphical representation of the Learning Ecology[10] that describes the learning paths of individuals in the framework of school and out-of-school science learning activities.*

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[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.

[9] Sotiriou, S., Bybee, R., & Bogner, F. X. (2017). PATHWAYS – A Case of Large-Scale Implementation of Evidence-Based Practice in Scientific Inquiry-Based Science Education. International Journal of Higher Education, 6(2), 8–17. https://doi.org/10.5430/ijhe.v6n2p8.

[10] https://www.nsta.org/connected-science-learning/connected-science-learning-march-2016/stem-learning-ecologies

A **Learning Ecology** is the physical, social, and cultural context in which learning takes place. Like natural ecosystems, learning ecologies (see Figure 2.1) have physical dimensions, which may or may not include easy access to nature, science museums, or advanced science programmes or internships. However, we are less used to thinking about the sociocultural dimensions of learning ecologies. Learning ecologies are the contexts—the physical settings, social interactions, value systems and histories—in which people learn over time, both daily and during the lifespan. Robust science learning ecologies, like their counterparts in nature, are characterized by diversity, redundancy, and local adaptations. This means that a robust science learning ecology contains a wide variety of programmes, across a range of institutions and places, allowing youth different and multiple ways to engage with science. In this framework, individuals take increasing levels of ownership over their own learning as they grow older and gain more experience. Several collaborative partnerships and networks are being created to optimize opportunities across a range of institutions and organizations (see for example the Open Schools for Open Societies partnership of institutions of formal and informal learning https://www.openschools.eu/).

2.1 Pedagogical Principles in the Design of the SEISMO-Lab Educational Scenarios

The SEISMO-Lab Framework aims to explore the idea of Learning Ecologies by developing educational scenarios (called SEISMO-Lab Demonstrators in the framework of the project) by providing access 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 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. The aim of the consortium is to formulate a common set of guidelines and recommendations 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. This framework builds on a four-strand model developed to capture what it means to learn science in school settings by adding two additional main strands incorporated for informal science learning, reflecting a special commitment to interest, personal growth, and sustained engagement that is the hallmark of informal settings.

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

Strands – 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.*

These Pedagogic Principles provide a framework for thinking about elements of scientific knowledge, innovation and practice. This framework describes a series of support functions that must be deployed for the long-term impact of the proposed activities to be safeguarded. Such support actions could include support for: the integration and coordination of educational and outreach activities between groups across different research institutions; the science community and scientists interested in educational and outreach activities; the education communities interested in scientific content and applications; special events and activities that provide means and tools for web-based communication and collaboration. This framework provides a useful reference for helping teachers and outreach groups in the informal science education community articulate learning outcomes as they develop programs, activities, and events, and further explore and exploit the unique benefits of introducing scientific research in schools. Furthermore, such an action asks for knowledge areas integration, effective and closes cross-institutional collaboration, and organizational change in the field of science education. In the following we are presenting the key issues related with the proposed strands in more detail.

2.1.1 Sparking Interest and Excitement

The motivation to learn science, emotional engagement, curiosity, and willingness to persevere through complicated scientific ideas and procedures over time are all important aspects of learning science. Recent research shows that the emotions associated with interest are a major factor in thinking and learning, helping people learn as well as helping them retain and remember. Engagement can trigger motivation, which leads a learner to seek out additional ways to learn more about a topic.

2.1.2 Understanding Scientific Content and Knowledge

This strand includes knowing, using, and interpreting scientific explanations of the natural and physical world. Students who are visiting science centres and museums, research infrastructures and other science related places come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science. Students also must understand interrelations among central scientific concepts and use them to build and critique scientific arguments. While this strand includes what is usually categorized as content, it focuses on concepts and the link between them rather than on discrete facts. It also involves the ability to use this knowledge in one's own life. Effective outreach programmes and on-line labs could provide great tools for the teachers who have to cope with an increased number of student's questions on complex topics related with scientific research.

2.1.3 Reflecting on Science

The practice of science is a dynamic process, based on the continual evaluation of new evidence and the reassessment of old ideas. In this way, scientists are constantly modifying their view of the world. Students reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena. This strand also includes an appreciation of how the thinking of scientists and scientific communities' changes over time as well as the students' sense of how his or her own thinking changes. Research shows that, in general, people do not have a very good understanding of the nature of science and how scientific knowledge accumulates and advances. This limited understanding may be due, in part, to a lack of exposure to opportunities to learn about how scientific knowledge is constructed and how scientific work is organised. It is also the case that simply carrying out scientific investigations does not automatically lead to an understanding of the nature of science. Instead, educational experiences must be designed to communicate this explicitly. Also compelling are the human stories behind great scientific discoveries. SEISMO-Lab will present unique such learning experiences emerging from the acquisition and the analysis of seismic data from numerous school-based seismometers.

2.1.4 Using the Tools and Language of Science

The myth of science as a solitary endeavour is misleading. Science is a social process, in which people with knowledge of the language, tools, and core values of the community come together to achieve a greater understanding of the world. The story of the discovery of Higgs boson (July 2012) and the observation of the giant black hole (April 2019) at the center of the Galaxy Messier are two good examples of how scientists with different areas of expertise and from numerous nations around the world came together to accomplish a Herculean task that no single scientist (not even a large research laboratory) could have completed on his or her own. Even small research projects are often tackled by teams of researchers. Through participation in informal environments, non-scientists can develop a greater appreciation of how scientists work together and the specialized language and tools they have developed (among them the web that was developed at CERN to support international cooperation in research topics). 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. 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.

Raspberry Shakes	Raspberry pi with TC1
R1388	SARG
R1784	SART
R1822	SAVL
R1C6C	SAZR
R3BC5	SIGU
R4EB6	SKAR
R4F38	SMES
R62B3	SNOA
R9AC0	SPRT
RA4CA	SSEA
RAC91	SSIGR
RC574	SSNT
RCBE2	STHS
RE950	SVOL
REC3A	
RF25A	
RG730	
RGF1A	
RI043	
RT080	
RT4F7	
RT53F	
RT56F	

Figure 2.2: *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 can gain appreciation of how scientists work together and the specialized 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.*

2.1.5 Identifying with the Scientific Enterprise

Through experiences in the framework of outreach and educational programmes, some students may start to change the way they think about themselves and their relationship to science. They think about themselves as science students and develop an identity as someone who knows about, uses, and sometimes contributes to science. When a transformation such as this one takes place, young people may begin to think seriously about a career in a research field, in an engineering firm, or in a research laboratory. Changing individual perspectives about science over the life span is a far-reaching goal of outreach and educational activities of the major research infrastructures. Sustaining existing science-related identities may be more common than creating new ones.

The strands are statements about what students do when they learn science, reflecting the practical as well as the more abstract, conceptual, and reflective aspects of science learning. The strands also represent important outcomes of science learning. That is, they encompass the knowledge, skills, attitudes, and habits of mind demonstrated by learners who are fully proficient in science. The strands serve as an important resource for guiding the design and development of the SEISMO-Labs for schools and especially for articulating desired outcomes for learners.

2.2 The Driving Forces of the SEISMO-Lab Framework

Two are the driving forces for establishing the SEISMO-Lab Framework for Establishing STEAM School Competence Labs, a new way of thinking on how schools work 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 Rethinking How Schools Work

There is a focused movement to reinvent the traditional classroom paradigm and rearrange the entire school experience — a trend that is largely being driven by the influence of innovative learning approaches. Methods such as project based and inquiry learning call for school structures that enable students to move from one learning activity to another more organically, removing the limitations of the traditional timetable. The multidisciplinary nature of these contemporary approaches has popularized the creative application of technology and fostered innovative designs of school models that link each class and subject matter to one another. As learning becomes more fluid and student-centered, some teachers and administrators believe that schedules should be more flexible to allow opportunities for authentic learning to take place and ample room for independent study. Changing how learning takes place in classrooms is also requiring shifts in the business models of schools, which are increasingly becoming more agile and open to trying new approaches.

This trend is largely a response to the overly structured nature of a typical school day, which some believe hampers learning. Traditionally, bells have signified the beginning and end of each day, ushering students from one class to the next. In many ways, the bell symbolizes the separation of disciplines, making a clear statement that each should be kept disparate. In the past few years, many teachers have made progress toward bolstering interdisciplinary learning, also commonly referred to as integrated studies. Edutopia describes this model as combining "curriculum from two or more disciplines, allowing students to see how ideas are connected." They point to collaboration, critical thinking, and knowledge retention as three positive outcomes for students. Technology use is at the heart of this design as activities such as integrating 3D printing in science classes and media production into humanities courses become more pervasive.

The goal is for students to understand the various intersections between different subject matter, acquiring a skillset that is desired in the contemporary workforce.

2.2.2 Shift from Students as Consumers to Creators

A shift is taking place in schools all over the world as students are exploring subject matter through the act of creation rather than the consumption of content. A vast array of digital tools is available to support this transformation in K-12 education; indeed, the growing accessibility of mobile technologies is giving rise to a whole new level of comfort with producing media and prototypes. Many teachers believe that honing these skills in learners can lead to deeply engaging learning experiences in which students become the authorities on subjects through investigation, storytelling, and production. Other components of this trend include game development and making, and access to programming instruction that nurtures learners as inventors and entrepreneurs. As students become more active producers and publishers of educational resources, intellectual property issues will become a key component of K-12 curricula.

There is growing support for empowering learners as creators that demonstrate their mastery in forms that surpass traditional tests and worksheets. Emerging instructional frameworks are encouraging teachers to use digital tools that foster creativity along with production skills. 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. Large scale initiatives as Open Discovery Space (http://portal.opendiscoveryspace.eu) have helped teachers streamline the process of creating, editing, and publishing educational materials. Such tools offer a way for teachers to develop digital lesson plans that are in line with the needs of their classrooms. As teachers become more comfortable using media, they can offer better guidance to their students.

2.3 Context of Implementation: Characteristics of the Open Schools

In the framework of the project the participating schools will be supported to set forward an innovation agenda that will help them to:

- Promote the collaboration with non-formal and informal education providers (science and research centers), parents and local communities to ensure relevant and meaningful engagement of all societal actors with science and increase the uptake of science studies and science-based careers, employability and competitiveness. With the focus on science learning in both primary and secondary education level the SEISMO-Lab innovation agenda proposes new and diverse models of collaborations between the above-mentioned stakeholders. By building on the best of current practice, the SEISMO-Lab aims to take us beyond the constraints of present structures of schooling toward a shared vision of excellence. Such an innovation programme holds great potential. If we want a powerful and innovative and open culture in schools that is self-sustaining, we must empower system-aware practitioners to create it, whilst avoiding simply creating interesting but isolated pockets of experimentation. We must instil a design-based approach of collaborative learning and inquiry between professional practitioners, thus creating a “pull” rather than “push” approach. To promote such an approach in the current schooling practices, an ecosystemic standpoint should be taken from the side of the remedying initiatives. More specifically, the latter should aim to capture the profiles, needs, contributions and relationships of all these school-related actors and elements towards a sustainable innovation ecosystem that will operate under a holistic framework of organizational learning and promotion of educational innovations.

- Become an agent of community well-being. SEISMO-Lab aims to support schools to develop projects that are proposing solutions to the needs of their local communities. To do so the SEISMO-Lab framework will explore the notion of well-being of the school's students (including concepts of equity, gender inclusion and empowerment). By creating a model of collaboration with local stakeholders and by using activities that require the involvement of different actors, the participating schools will be linked with their local communities in a much deeper level. The adaptation of the activities will entail linking their subjects to issues of national interest in connection with the grand global challenges. Schools will thus aim to "act locally but think globally", a motto developed already a few years now but still far from the reality of the majority of schools in Europe today. In this way, these schools will enrich the science capital of the local communities and will promote responsible citizenship.
- Promote partnerships that foster expertise, networking, sharing and applying science and technology research findings and thus bringing real-life projects to the classroom. The project partners, both individually and in collaboration, have been developing, testing and promoting innovative educational applications and approaches for European schools (supported by relevant appliances and resources) for many years, which promote sharing and applying of frontier research findings in schools, supporting the developments of 21st century competences through creative problem solving, discovery, learning by doing, experiential learning, critical thinking and creativity, including projects and activities that simulate the real scientific work (e.g. analysing seismological data, estimating the epicenter of previous earthquakes, analysing waveforms to produce sounds, construction and using scientific instrumentation). Each school will bring together representatives from industry and civil society associations who – in cooperation with school community – will scan the horizons, analyse the school and community needs and will cooperate to design common projects and to propose innovative solutions.
- Focus on Effective Parental Engagement. The innovation agenda builds on the notion of science capital of schools' communities. Whilst science and technology are often seen as interesting to young adolescents, such interest is not reflected in students' engagement with school science that fails to appeal to too many students. Girls, in most European countries channel away from science and only a minority of girls pursues careers in physical science and engineering. The reasons for this state of affairs are complex but need to be addressed. Many students who express high levels of interest in science may not choose science subjects because: a) they think that choosing science leads only to working in a laboratory; and, b) that science is for other people. These are issues of identity – of science and of the students themselves. For example, the role of students' families in their selection of future career has been much stronger than what previously expected. So, what can be done to modify this situation? The SEISMO-Lab framework is suggesting four courses of action: effective parental engagement in the projects that will be developed by a) Planning: Parental engagement must be planned for and embedded in a whole school or service strategy. The planning cycle will include a comprehensive needs analysis; the establishment of mutual priorities; ongoing monitoring and evaluation of interventions; and a public awareness process to help parents and teachers understand and commit to the Open School Development plan. b) Leadership: Effective leadership of parental engagement is essential to the success of the SEISMO-Lab framework. A parental engagement programme is often led by a senior leader, although leadership may also be distributed in the context of a programme or cluster of schools and services working to a clear strategic direction. c) Collaboration and engagement: Parental engagement requires active collaboration with parents and should be proactive rather than reactive. It should be sensitive to the circumstances of all families, recognise the contributions parents can make, and aim to empower parents. d) Sustained improvement: A

parental engagement strategy should be the subject of ongoing support, monitoring and development. This will include strategic planning which embeds parental engagement in whole-school development plans, sustained support, resourcing and training, community involvement at all levels of management, and a continuous system of evidence-based development and review.

- Teach science for difference: Gender Issues. Instructional methods that foster students' understanding while allowing for different educational methods to be implemented in science classes might contribute to girls' participation and performance in advanced science classes while also supporting the learning of many boys. By implementing approaches that respect the fact that students are individuals with different needs and by applying a variety of methods, and approaches in the classroom the school may create more gender inclusive classrooms that would appeal to different types of learners and not the so called 'implied learner' that typical school lessons are designed for. This could be accomplished by for example sharing ideas, arguing, asking questions and analyzing data in small groups of students who work in collaborative manner. This is an approach that clearly reduces the competitive nature of the whole classroom (teacher-centered) approach. The SEISMO-Lab educational activities and projects are based on pedagogical approaches that produce the outcome of proportional participation of all genders. More specifically the proposed standardization process will:
  - Adopt and integrate informal and formal educational experiences that intervene and reverse traditional patterns of low participation; encourage all students interest and girls in particular, enthusiastic participation, and election of continued study in math and science; increase confidence; and give girls positive images of math and science learning and careers.
  - Integrate awareness of gender bias in educational environments, and change organizational commitment, policy, and action to remedy under representation through student and faculty programs, for example, undergraduate departments in engineering, physical science, or computer science making a concentrated effort to increase recruitment and retention.
  - Adopt and integrate new courses and curriculum that are gender-neutral or appeal particularly to girls and women. For example, think about including individual work, group work, and dyad interactions during the time of a lesson to involve a variety of different interaction forms and accommodate the needs of different students.

SEISMO-Lab will identify the "design features" to be adopted, its theoretical basis and the research or evaluation basis for the "model," and address the benefits and issues bearing on integration in their educational setting.

2.4 Design Features of the SEISMO-Lab Educational Activities

The activities that will be implemented in the participating schools are based on the essential features of creative learning including exploration, dynamics of discovery, student-led activity, engagement in scientifically oriented questions, priority to evidence in responding to questions, formulations of evidence-based explanations, connection of explanations to scientific knowledge, and communication and justification of explanations. These elements support creativity as a generic element in the processual and communicative aspects of the pedagogy and proposing innovative teaching strategies that will offer students high participation and enable them to generate highly imaginative possibilities.

At the same time, the SEISMO-Lab framework is based on the main principles of Responsible Research and Innovation process: learners' engagement, unlock of their full potential, sharing results and provide access to scientific archives, designing innovative activities for all.

Based on that, the participating schools will promote a series of educational activities in the form of real-life projects that will utilize innovative ideas and creativity and empower students to actively engage themselves in the learning process and improve their conceptual understanding in various scientific topics. It is therefore intended that the educational practices and strategies presented will allow science educators and specifically late primary and early secondary school teachers to identify creative activities for teaching science. Furthermore, the proposed pedagogy will aim to enable teachers to either create new creative activities or to properly assemble parts of different educational activities into interdisciplinary learning scenarios. In the framework of the SEISMO-Lab project the proposed activities will have the following four characteristics. They must be

- **Placed:** The activity is located, either physically or virtually, in a world that the student recognizes and is seeking to understand.
- **Purposeful:** The activity feels authentic, it absorbs the student in actions of practical and intellectual value and fosters a sense of agency.
- **Passion-led:** The activity enlists the outside passions of both students and teachers, enhancing engagement by encouraging students to choose areas of interest which matter to them.
- **Pervasive:** The activity enables the student to continue learning outside the classroom, drawing on family members, peers, local experts, and online references as sources of research and critique.

These four criteria can provide a useful checklist for teachers formulating their learning designs, but also suggest what a science classroom and a school as an organization needs to offer to become more engaging in itself: a place-based curriculum, purposeful projects, passion-led teaching and learning, and pervasive opportunities for research and constructive challenge.

These activities will be adapted by the school community that will involve representatives from educational providers, industries, civil society associations and even students themselves. The activities used in the project will promote collaborations and the opening up of the classrooms to the society. The participating schools will include both primary and secondary education level and activities will be selected and adapted accordingly to fit the different levels.

2.5 Supporting Schools to become Sustainable Innovation Ecosystems

In our view the open school environments should provide more challenging, authentic and higher-order learning experiences, more opportunities for students to participate in scientific practices and tasks, using the discourse of science and working with scientific representations and tools. It should enrich and transform the students' concepts and initial ideas, which could work either as resources or barriers to emerging ideas. The open schools' environments should offer opportunities for teaching tailored to the students' particular needs while it should provide continuous measures of competence, integral to the learning process that can help teachers work more effectively with individuals and leave a record of competence that is compelling to students.

The involvement of the schools to the SEISMO-Lab project does not impose the implementation of a specific strategy towards openness. Through the intensive collaboration between the school community and the SEISMO-Lab team we are aiming to examine every collaboration as a separate case. In all cases however the project's team goal is to provide valuable guidance and to develop a sustainable support mechanism to assist both the school leadership as well as the teachers during the transformation process. In this report we are going to present a strategic implementation model and related milestones that could as a pathway towards the implementation of innovation in the school setting.

It must be noted though, that in each school case, in each participating country, multiple factors have to be examined before a design and implementation model will be placed in action. Factors taken into account in each case are: Local legislation and educational policies currently in place, Local educational culture, Current status of the school(s) in regards to existing curriculum/existing educational resources/ selected pedagogical approaches, Current status of the school(s) in regards to administration/teacher readiness towards embracing educational innovation and adopting an open schooling culture, Current status of the school(s) in regards to existing technological infrastructure, Current status of collaborators (government officials/school administrators/teachers/students), Scale of collaboration in regards to number of schools/teachers/students/other participants, Duration of collaboration and Total budget allocated.

In Europe there are many different school systems. An important and very crucial parameter for the introduction of innovation in the school setting is the level of autonomy at school level and the different levels of authority within the schools. The major challenge for SEISMO-Lab project is to find ways to propose activities and approaches that could be used from school heads mainly in countries with a relatively low level of autonomy (Greece, Italy, Romania, Turkey and Cyprus).

The SEISMO-Lab framework can be perceived as an organisational change methodology, enabling the change agents to introduce the innovative SEISMO-Lab approach. Well known organizational change methodologies prescribe a recommended pathway of stages or phases, consisting of particular activities to work through in order to achieve lasting change. In comparison with the most popular organisational change methodologies, the SEISMO-Lab framework includes the following steps in order to be regarded as suitable for education systems with a high level of autonomy at the school level:

- **Inspiration and Establishment of the need for change**: In some western European countries, teachers and school heads jointly decide on their pedagogic choices. In a few countries, the teachers have the final say in this matter. For both the innovative schools and the more traditional schools this proposed step is a vital part of an innovation implementation plan. In innovative schools there is a need to inspire teachers because the SEISMO-Lab initiative may be one of several proposed innovations that a school implements. Therefore, the teachers need to be convinced that the SEISMO-Lab project is more relevant than other options. In traditional schools the emphasis could be put on the urgency to change. These schools (the vast majority of schools in Europe) have less experience with innovative projects. The school heads and teachers at these schools should be made aware of the need to change. This step, the inspiration of teachers and staff should be considered as a continuous process during all phases of the implementation and in most instances one of the main tasks of the school head.
- **Establishing a change team**: In most schools, innovations start small. A few innovative teachers, together with the school head lead the way and enthuse their colleagues during the implementation. School heads will initially engage teachers with low levels of resistance to change. During the project phases, teachers often look for other change agents to further implement the project in other subjects as well. The school head's role is to find the first few change agents and facilitate their work. This support could include an appropriate time compensation scheme.
- **Empowering the change team**: The change agents should be supported by the management of the schools during the implementation phases. Preferably, the change agents will be

regarded as role models in their schools. Secondly, the change agents need to be supported by the continuous inspirational efforts of the school heads.

- **Organisational change**: Implementing change requires a teacher to experiment with innovative (from the teachers' perspective) pedagogic approaches. From an organisational perspective, the school head will need to implement an environment that supports experimentation by celebrating success and regarding failures as unique chances to learn. In true learning organisations, teachers are supported to take necessary risks (all changes come with risk taking and perceived uncertainty) and feel appreciate when they share the successes and failures.

2.6 Viable Change: Sustainability as a route to the future

The SEISMO-Lab framework put emphasis on creating viable change to school settings that lasts and expands. The proposed approach aims to create strong school networks which are ready to share their experiences with others. It is built on numerous national and international initiatives and provides a unique resource for a school reform towards a more effective school environment. Thinking about the future or even performing isolated experiments is not enough for decision makers in education. It is also necessary to conceptualize how to change current systems in specific powerful ways. System thinking in action addresses sustainability and the need to change context. How do contexts or systems change? They do so over a very long period. System change evolves because of major alterations in demographics, technology, and other social forces. But we want to accelerate the development of good changes like the spread of professional learning communities. The key to this involves conceptualizing sustainability and using leadership to change context or the environment by a) increasing leaders' participation in wider contexts and b) helping to develop leadership in others so they can do the same.

After many years of working on European-wide reforms (including the Opening-Up Education Initiative by the EC, in 2013), the SEISMO-Lab consortium noticed the following phenomenon: Individual school heads became almost as concerned about the success of other schools in their areas as they were with the success of their own school. This is a direct result of being engaged in a larger purpose and getting to know other schools through walk-throughs and other lateral capacity-building strategies. These strategies might involve small clusters of schools working together to improve literacy or principals and teachers conducting walk-throughs of a school or schools to provide critical feedback to the staff. Their world-views and commitments increased to encompass the larger system, but at the same time, they helped change the very system within which they work. They literally changed their context. The key to sustainability is to change context: "Sustainability does not simply mean whether something will last. It addresses how particular initiatives can be developed without compromising the development of others in the surrounding environment now and in the future". Sustainability is about changing and developing the social environment. The SEISMO-Lab framework is not about the proliferation and the development of single schools; it is about creating new environments across the system through tri-level development, at school level, at the community level and at national level. The following eight items are elements of sustainability and part of the writ large agenda:

- Public service with a moral purpose is an explicit commitment on the part of the system to endorse and pursue an agenda for raising standards and closing the gap.
- Commitment to changing context at all levels involves the realization by leaders at all levels that they are changing the culture of schools and districts.
- Lateral capacity-building through networks means identifying and investing in strategies that promote schools learning from each other.
- Intelligent accountability and vertical relationships focus on developing great self-review capacity in the context of transparent external accountability.

- Deep learning means that the system is continually pushing the envelope to address the fundamental learning goals of thinking and problem-solving skills, teamwork, and learning across the curriculum.
- Dual commitment to short-term and long-term results requires system leaders to realize that they must pursue simultaneously short-term increases in student achievement and mid- to long-term results. They must lay the foundation for the long-term learning of all students.
- Cyclical energizing emphasizes that “achievement at all costs” is self-defeating. Capacity must be built over time. Periods of intense development must be coupled with opportunities to recoup. Sustainability is about energy more than it is about time. Thus, monitoring and stimulating energy are key.
- The long lever of leadership—leaders fostering the development of other leaders by widening their sphere of commitment and participation—is an integral part of this agenda. In this sense, the main mark of a school principal at the end of his or her tenure is not just his or her impact on the bottom line of student achievement, but equally on how many good leaders he or she leaves behind who can go even further. This is the long lever of leadership. Leaders also need to help provide wider learning experiences through networks, clusters, paired schools, and other lateral capacity-building strategies.

Learning from each other concept is a very crucial point in moving this ambitious agenda forward. We know this but need to address it explicitly with respect to tri-level reform. School cultures improve when teachers within the school learn from each other on an ongoing basis. Communities cultures improve when schools learn from each other, and when local communities learn from one another. When schools or their communities want to know where to start reform, they would be wise to conduct site visits to other schools or communities that are further down the road. During a site visit, teams from the visiting school or it community prepare questions for the host school and then gather data to address these questions. They then examine their findings and identify specific actions to take. The current organization of the ERASMUS+ programme for schools’ cooperation and exchanges offers unique opportunities for this to happen even at an international level. This is an example of continuous learning that includes seeking out better information and learning from one’s own experiences and from the experiences of others. In addition, member states engaged in tri-level reform need to learn from each other (both within and across countries). The learning principles are no different, just applied on a larger scale. Paying attention to the growing knowledge base, problem solving and learning through reflection, cultivating networks of interaction, and enlarging the world view are all part and parcel of increasing capacity and changing.

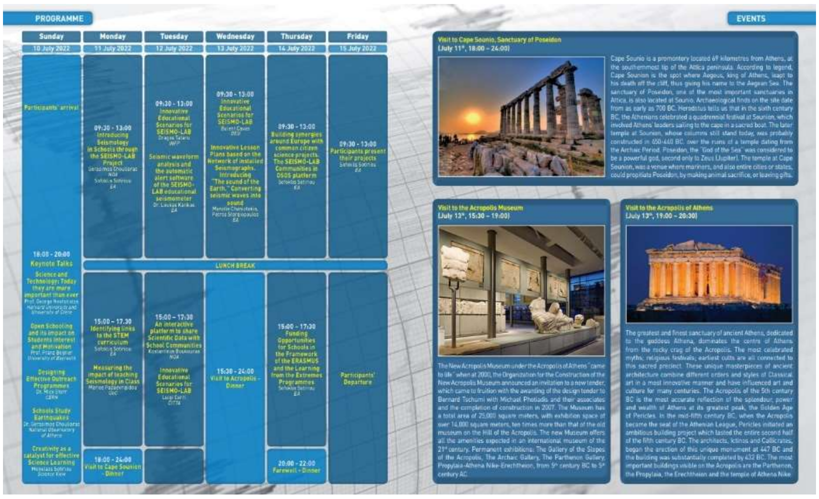

Figure 2.3: *SEISMO-Lab Professional Development Course programme brought together 25 teachers from the participating countries to co-design the SEISMO-Lab educational activities. ERASMUS+ Programme and mobility actions offer a unique framework for such participatory activities.*

Finally, it would be a fundamental misunderstanding of systems theory to assume that the system should change first. Each of us is the system; there is no chicken and egg. We must connect with others to change whatever parts of the system we can. Whenever one is acting to promote professional learning communities, there should be an obligation to connect it to larger issues—bigger dots, if you will. Waiting for others to act virtually guarantees preservation of the status quo. If individuals are proactive, they stimulate others and make it more likely that the system will begin to change, resulting in new breakthroughs.

3 Guiding Principles

3.1 Practices for SEISMO-Lab project Implementation

In an open schooling environment, it is important for school heads and teachers to recognize that there are key conditions that support deeper learning outcomes, and that these conditions are sequential and rely on and build upon one another. 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[11]:

• Empower learners
• Contextualize knowledge
• Connect learning to real world experiences
• Extend learning beyond the school
• Inspire learners by customizing learning experiences
• Purposefully incorporate technology to enhance learning

For teaching to shift to facilitate powerful learning experiences - where students are empowered and inspired and learning is contextualized, connected to real life, wired, and extended beyond school - the role of the teachers must change to that of learning strategist. 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.

3.1.1 Empowering students as learners

Teachers who focus on deeper learning see their first responsibility to empowering students. For this reason, they use pedagogical approaches that help learners become self-directed and responsible students rather than passive rule followers. The centerpiece of instruction is helping students develop an understanding of learning as a complex and ongoing process that entails seeking feedback, revising work and regularly reflecting on what one has produced, as well as on the choices and decisions made throughout the learning process. "Revision toward mastery" is therefore a main feature of the culture and the language used by schools committed to deeper learning[12]. Teachers provide feedback, as well as opportunities for students to receive feedback from peers, reinforcing the idea that learning does not end with their first effort. 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.

3.1.2 Contextualize knowledge so it is coherent

Teachers who work to achieve deeper learning student outcomes also contextualize knowledge so it is coherent as a way to help learners acquire content knowledge. Teachers use guiding questions, common themes, and big ideas to provide a context for every assignment, classroom activity, and project. Teachers are involving students in project that are relevant to them and to the local communities. Teachers also can involve learners' projects related to global challenges or major discoveries that changed our understanding about the world. Teachers often work

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

together across multiple subjects to design integrated learning experiences to connect their otherwise separate subject-specific content.

3.1.3 Connect learning to real issues and settings

Teachers who focus on developing deeper learning competencies connect learning to real issues and settings to make it more meaningful for learners. Teachers ensure that there are frequent opportunities for learners to experience workplace conditions and expectations and address real world challenges and problem solving by interacting with professionals and experts in relevant fields, taking on a professional role when doing a project, or by connecting historical events to current issues.

3.1.4 Extend learning beyond the school

In addition to connecting to the "real" world, deeper learning-focused teachers find ways to extend learning beyond the school and construct powerful student learning experiences in a range of settings. As a result of long-term formal and informal relationships with research centers, science centers and outreach groups, the classroom walls drop away and the entire community becomes an annex of the school in which learners have access to rich content, outside experts, additional resources, an authentic place and context for learning, and work-based experiences.

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: *Modeling 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.*[13]

3.1.5 Inspire students by customizing learning experiences

Teachers who focus on deeper learning inspire learners by customizing learning experiences. Teachers are intentional in establishing strong relationships with learners for the purpose of finding what will ignite their interest to pursue their own learning. Teachers use independent projects to both customize learning and provide inspiration for all their students.

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

3.1.6 Use technology in service of learning

Teachers who focus on developing deeper learning competencies use technology in service of learning. Teachers purposefully incorporate technology to enhance, rather than automate learning; regularly employ technology tools to support student learning and to engage learners in their own education; and shift their role away from being the sole gatekeeper to knowledge.

3.2 Key Conditions that Support the Development of an Open Schooling Culture

For teaching to shift to facilitate powerful learning experiences like the ones described above - where students are empowered and inspired and learning is contextualized, connected to real life, wired, and extended beyond school - the role of the teacher has to change to that of learning strategist. 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. Therefore, in the framework of SEISMO-Lab implementation, it is important for the national coordinators, the school heads and the teachers to recognize that there are key conditions that support the development of an open schooling culture and strategies, and that these conditions are sequential and rely on and build upon one another. The cornerstone condition is a school-wide culture that focuses on learning and promotes the belief that everyone is collectively responsible for student outcomes.

3.2.1 Establish a learning culture

First, a learning culture must be established that values the need to learn, as well as students' need to learn how to learn, to become self-directed, and to develop an academic mindset that potentially will help them to consider scientific careers in the near future. This culture is established or signalled most through the creation of a clear and visible set of core values that are then reflected in the design of the school, the way in which students are introduced to and oriented to the school, what is assessed, and the consistent language used across the school, including what is posted on the walls. An understanding and reflection of these core values can be seen in everything from the language that teachers and students use to talk about learning to the way the school interacts with the community.

3.2.2 Create shared responsibility for student learning

The corresponding condition in support of teaching in an open school is a culture in which everyone is collectively responsible for student learning. This culture has to be purposefully established for students and teachers alike, and is most commonly developed by building relationships that ensure students are known well by both adults and peers, and that there are regular and systemic opportunities for frequent conversations among teachers, students, peers, and other adults.

3.2.3 Establish a culture of trust and professionalism

Furthermore, it is important to establish a culture of trust and professionalism as a condition that supports learning in an open school environment. The shift in culture is critical to making sure teachers feel supported and empowered to take on new roles, and to ensure that daily work and interactions are aligned to the open schooling plan and vision. Trust empowers individuals to be their best selves and creates a sense of shared accountability between and among the staff. Shared accountability can encourage greater feelings of trust among teachers and between teachers and school heads. School heads who trust teachers and treat them as professionals may also invite teachers to share in the leadership of the school with them, meaning teachers have substantial influence on school-based decisions, especially around issues of teaching and learning. Teachers feel more comfortable wearing multiple hats—formally and informally assuming roles such as grade-team coordinator, teacher mentor, teacher leader, and coach. In this new paradigm, teachers also often take on responsibilities many principals save for themselves, such as hiring staff, creating school schedules, developing partnerships with out of school organizations or businesses, and even dealing with funders. In a culture of trust and professionalism, school heads value their teachers' vast experiences and wealth of knowledge and want them to be active participants in the construction and tailoring of professional development. Because teachers design their own professional development, they are very engaged and work productively with their colleagues to ensure that professional development is growth-driven, collectively constructed, context specific, and embedded in the school.

3.2.4 Preserve time for teachers to collaborate

These shifts in culture and roles require settings that foster deeper the open schooling culture and establish and respect time for teachers to collaborate. During this collaboration time, teachers can draw upon each other's expertise to design or revise meaningful learning experiences for students; address problems impacting the classroom and the school at large; and strategize how to improve their individual practice and student learning. Structured opportunities to work together can take the form of teacher-directed and school embedded professional development by peers or third parties on how to use specific pedagogical approaches. They can focus on feedback from classroom observations from instructional coaches or teaching peers on one another's teaching practices. Teachers can also use their structured time together to identify and share the technology tools, apps, or resources they have found to assess students for mastery of content and critical thinking as well as other skills and personalize instruction to meet the unique learning needs of each student.

4 Strategies

In chapters 2 and 3 we have described the SEISMO-Lab framework, the proposed context of implementation, the key features and characteristics of the project activities, the practices and the conditions that must be in place to support the development of an open culture in the school communities. We have tried to summarize the main challenges to introduce the SEISMO-Lab framework in school settings across Europe and the characteristics of teaching in open schooling environments to make sure that the participating schools, the school heads and teachers are fully realizing the different aspects and conditions of the proposed intervention. Now we need to define in practical terms for the consortium, the school heads and the individual teachers, the tailored Strategies to support the local schools as they transform themselves into open schooling environments while they are implementing the SEISMO-Lab framework. Guidance will be also provided to schools, local-level stakeholders through-out the project pilot implementation.

4.1 Different Schools - Different Strategies

The SEISMO-Lab strategies exemplify the project's overall approach on how we can best support schools in their attempt to evolve, transform and reinvent their structures towards a more open, localised and socially responsible learning environment. In this framework, schools will facilitate open, more effective, and efficient co-design, co-creation, and use of educational content (using the project collection of digital objects and the proposed educational pathways), tools and services for personalized science learning and teaching that will form the basic ingredients for innovative student projects. Such projects, understood as best practices are the so-called SEISMO-Lab Demonstrators in the framework of the project.

In the following section a series of strategies, each addressing a particular type of schooling environment, in relation to its openness, uptake of innovation and responsibility, will be explored.

4.1.1 Innovation & openness for beginners: from individual efforts to holistic action plans

Schools that are at an initial stage in relation to innovation and openness, are offered needs-analysis tools that aim to identify areas that are in need for immediate action and modernisation, such as CPD, use of ICT, creation of educational content, participation in communities of peers and others. Schools will be supported by the project partners (science centres and museums) to co-develop an initial Educational Scenario (see Chapter 6 for different templates) that will describe their students' journey in scientific discovery and exploration. The next step is the organisation of a core group of teachers who will act as Change Agents: These are innovative teachers who will share the vision of the school community to take the school to the next level.

What is the mission of a change agent?

- **A pioneering teacher who leads the team of the participating teachers from each school, and:**
- Takes initiative in order to implement innovative practices that aim to have **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 organizational changes
- **Explains why innovation is important to ensure long-term success**

Also at this level, initial innovative scenarios are being implemented to pioneer future-oriented practices and to experiment with scientific data and resources, as well as with innovative technological services and practices. At this phase, the SEISMO-Lab project will offer a rich database of creative initiatives with access to numerous high-quality resources, guidelines and support (see Chapter 5) as well as examples for the coordination of action plans offering funding opportunities for the realization of the school action plans focusing on teachers' professional development and the adoption of a School Development Plan for the participating schools. Tools that will be offered to schools at the stimulation phase will include Teachers' Guidelines, a School Leaders Tool Kit and Community Building Tools. The SEISMO-Lab strategy at this phase is to stimulate the teaching and learning processes based on a series of effective instructional models for science education (see Chapter 6). Teachers need time to re-visit their own perspectives and experiment in their own classrooms. At this level, it is expected that inquiry is becoming a powerful and versatile pedagogical approach that will eventually lead to the birth of student-led science projects. Community building tools are key elements at this stage. They support relationships and alliances within schools and between schools and local players, help localization of the success experiences (best practices turned into local projects), and understanding of how structures, hierarchies and learning cultures will adopt the change. Here, teachers and students adopt well-designed educational practices and foster their use and spread (over to other colleagues initially), to facilitate the incubation of educational innovations and communities of practice. The teacher must reflect on the organizational change and learning cycles for implementation. Finally, the teacher should contribute back to his/her community, resulting in new collaboration and networking. Novel learning practices and educational experiences must foster to search, reflect upon, and create things that can be eventually delivered out of the educational environment, exchanged and assessed with and by others in the school. The outcome of previous educational experiences (projects, ideas, etc.) can incubate future ones that are derived from the originals.

A school's current needs in relation to innovation and openness will be assessed by looking into certain relevant strengths and weaknesses. The proliferation of online communication and, therefore, of online communities has offered a number of further advantages to peer learning and teacher professional development. These include the tackling of time limitations in traditional training, the offering of both synchronous and asynchronous engagement and the equal participation of all community members (again, as opposed to traditional instructive training) that increases the democratic character of this particular context. Above all, online communities offer access to both the latest educational technology (such as web 2.0 tools), as well as to useful insights on how to best implement them through best practices that peers are willing to share with their colleagues. SEISMO-Lab will facilitate the building of various forms online communities (school, thematic, international, etc.) to support teachers to create, use and share digital resources relating to science student projects with an emphasis on social responsibility Communities that focus on particular RRI principles and how to incorporate them into the school culture, as well as at more advanced levels are of great importance and will serve the general strategy of school opening up.

4.1.2 Introducing innovation to competent schools: from essential change to acceleration

These schools have strong capacity to innovate, they are implementing local projects and activities, but they are operating in isolation and usually they are missing numerous opportunities to integrate external resources to their plans and programmes. Communities of teachers are operating at local level while the content and the material produced are not shared with external communities. The implementation of the educational scenarios is valid here. It could be a helpful tool for the school management who must be committed to change to initiate a series of activities that will help the educational staff to realize the added value of the innovation process. The introduction of the Educational Pathways could help schools to develop to incubators of innovation. Attention is given to exploiting knowledge management techniques (sharing what is known within the participating school communities) and synthesizing evaluation and accelerating diffusion within national agencies (to reach more users). Insights from the use of data from the school communities, the development of the teachers' competence profiles, the content that was created and delivered locally, the interaction of the communities and their members will create a unique data base for future recommendations and for the identification of best practices. SEISMO-Lab will propose initial scenarios for the introduction of the project's methodology in the participating schools while schools will be encouraged to create networks that will implement the proposed activities. Training on the preparation of etwinning projects or KA1, KA2 Erasmus+ mobility and school-based projects applications could be a nice process to introduce schools in the international cooperation field while at the same time significant resources could be allocated to the PD programme of the school. SEISMO-Lab Demonstrators, that will be available on the project's website could also be helpful here supporting innovative schools to develop their ideas to new localised projects that could provide new solutions for the school and its community, for bringing the gap between formal and informal learning settings and creating new opportunities for personalisation at different levels (student, teacher, school). Partner science centres and museums will support the design and development of the new localised educational scenarios and will provide a framework for the implementation of large-scale projects (beyond the school). Project partners are already implementing such activities. SEISMO-Lab, through an extended network of universities, research centres and facilities, will be enriched by integrating various project activities and trying to cover the school needs and interests.

4.1.3 From innovative schools to RRI-enriched learning commons

In this category schools have well established innovation plan, they have already introduced a culture of sharing while they have well established cooperation with other schools and with external stakeholders. The SEISMO-Lab strategy for these schools is to emphasise on the integration of the RRI culture in the school setting. The role of research and innovation (R&I) involves every key stakeholder (including policy-makers, researchers, industry and commerce, science educators, and civil society organizations as well as the public at large). SEISMO-Lab strategy development here foresees a series of tools that guide the introduction of RRI in different educational organizations both in formal and informal learning sector (developed by RRI Tools initiative). It will offer a handbook for schoolteachers (along with a series or self-reflection tools) with the main aim of accommodating RRI practices in schools, and particularly in the teaching of STEM disciplines (science, technology, engineering and mathematics). RRI principles are close to many aspects of innovative teaching methods. The way from innovative school to RRI learning common can be done through a number of pedagogical methods such as IBSE, structured research school projects or through reflections on ethical, legal and social aspects and basic socio-scientific issues based on a range of inspiring resources for designing and implementing class activities are included (RRI-Tools, 2016)[14].

Aside from the SEISMO-Lab Demonstrators and support materials mentioned in the previous sections that will be also employed to school level, the consortium partners will provide recommendations to school leaders for strategic holistic school improvement. These recommendations will be produced by utilizing rule-based inter-relations. Furthermore, these recommendations will be aligned with the typical elements of the schools' European

[14] RRI-Tools, 2016. https://www.rri-tools.eu/-/rri-in-practice-for-schools-handbook-for-teachers

Development Plan (EU, 2015)[15] to support school leaders' planning. More specifically, examples of recommendations to be provided can include:

- Recommendations on specific RRI principles to be incorporated into the School Development Plan and recommendations regarding particular SEISMO-Lab Demonstrators that are relevant to local social issues. In this context, the SEISMO-Lab Demonstrators will align local challenges facing the community that hosts the school with particular science education scenarios and the ability of the school and its community (teachers, students, etc.) to take up such tasks. Recommendations on the development of effective cooperation with organizations like museums and science centres, research centers, enterprises, industries and the local communities.
- Recommendations of potential partner schools with similar (or complementary) profiles so as to support collaborations and mutual improvement. Such activities are heavily supported in the European context within a range of initiatives, including ERASMUS+ staff mobility (e.g., teaching staff shadow teaching), eTwinning (e.g., joint teaching projects) and ERASMUS+ strategic partnerships (e.g., teaching staff formal training activities).
- Recommendations of professional development courses to meet the specific competence needs of the teaching staff. This recommendation type will match the competence profiles of teaching staff and the descriptions of professional development courses in terms of competences they cultivate so as to identify targeted training opportunities.
- Recommendations regarding improvement of the use of ICT in the teaching practice (i.e., educational designs) employed in the school. This recommendation type could analyze the educational designs used in the school in terms of the level/type of ICT exploited, and generate potential recommendations for enhancing this level in case of low ICT use. Additionally, these recommendations should also take into account the teaching staff ICT competence profiles, so as to provide personalized suggestions that the teaching staff will be competent to employ Recommendations of educational designs. This recommendation type could suggest educational designs employed in one school to the teaching staff of another school, based on the similarity of school innovation profile. In that way, teaching staff will be able to select educational designs which have been successfully employed in schools with similar innovation profile to their own[16]. Furthermore, these recommendations should also consider the teaching staff ICT competence profiles, so as to provide personalized suggestions that the teaching staff will be competent to employ.

The recommendations will be provided to the interested school leaders in the form of school innovation actions. The school heads will be able to explicitly define which recommendations they implemented, so as to a) provide a means to validate the proposed approach's impact on school improvement and b) provide a means to build effective educational scenarios templates. These templates (see Chapter 6) will be formulated based on the specific actions that schools implemented (supported by the provided recommendations) towards improvement and could be shared for streamlining the adoption from other schools with similar initial profiles. This kind of open innovation streamlining is highly required to replicate successful innovation development in a wider scale.

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[15] EU (2015) A practical guide for school leaders https://www.schooleducationgateway.eu/guideforschoolleaders/downloads/en/Practical-Guide-for-School-Leaders-EN-FINAL-PDF

[16] Sergis, S., & Sampson, D. (2016). Learning Object Recommendations For Teachers Based On Elicited ICT Competence Profiles, IEEE Transactions on Learning Technologies 9 (1), 67 – 80

The SEISMO-Lab Demonstrators that will be adopted at this level will have all the qualities of complete scenarios guiding student-led projects. However, and since in these cases we are dealing with school that are innovative and generally open, the basic ingredient is a set of the most up-to-date RRI guidelines supporting schools not only to study and incorporate local issues into their science teaching to attempt a long-lasting impact in their communities. In this context, Gender equality is not only a principle that must govern the schools' profile and/or science teaching for example (female role models in science), but must a fundamental element of increase collaborations with parents, local groups, business, etc. in which (the collaborations) the school plays a pivotal role in the offering solutions and tools to stakeholders to improve their own uptake of such a principle. In other words, these schools with these types of accelerators will be in a position to enlighten, train, support through their own projects local stakeholders in need of such change.

4.1.4 Reinventing schools: forward looking scenarios and future classrooms

The aim of SEISMO-Lab consortium for proposing strategies for schools that have already achieved a high level of openness in their operation is twofold. The first one is that we are considering sustainability as a route to the future. The SEISMO-Lab framework put emphasis on creating viable change to school settings that lasts and expands. The proposed approach aims to create strong school networks which are ready to share their experiences with others. The second reason is that education systems simply must evolve. Three words sum up the change that must happen: experimentation, independence, and sharing. Schools must then be given the freedom to test, assess the experiments, abandon those which fail or are too costly, learn lessons, and disseminate and reproduce the successful ones on a larger scale. The schools that have manage to achieve the higher levels of openness have to act as drivers of this change. And they will need significant support to play this crucial role.

The SEISMO-Lab framework (along with online platform and teachers' space which will be in place) will facilitate the development of school networks with these schools as core nodes and reference points. Sustainability in this context does not simply mean whether the open schooling model or the proposed approaches will last. It addresses how particular initiatives can be developed without compromising the development of others in the surrounding environment now and in the future. Sustainability is about changing and developing the social environment. The SEISMO-Lab framework is not about the proliferation and the development of single schools; it is about creating new environments across the system through tri-level development, at school level, at the community level and at national level. Learning from each other concept is a very crucial point in moving this ambitious agenda forward. We know this but need to address it explicitly with respect to tri-level reform. School cultures improve when teachers within the school learn from each other on an ongoing basis.

Open schools are moving towards outcome-based education (see Table 4.1). Flexibility and diversity are the main guiding principles here. The school curricula are adopted to the local needs while the student-led projects are the norm. While the common feature in global education policy has been emphasis on scientific literacy and numeracy with strong emphasis on structural knowledge of systems, technical skills, and cognition in the open school environment all school subjects are emphasized, giving equal value to all aspects of an individual's personal development, whether they be moral, creativity, knowledge or skills based. The current trend in the educational systems in Europe has been consequential accountability systems for schools. Success or failure of schools and their teachers is often determined by standardized tests and external evaluations that only devote attention to limited aspects of schooling, such as student achievement in science, mathematical and reading literacy. An open school a different direction is chosen: trust through professionalism. A culture of trust within the education system values teachers' and headmasters' professionalism in judging what is best for students and in reporting on progress of their learning.

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

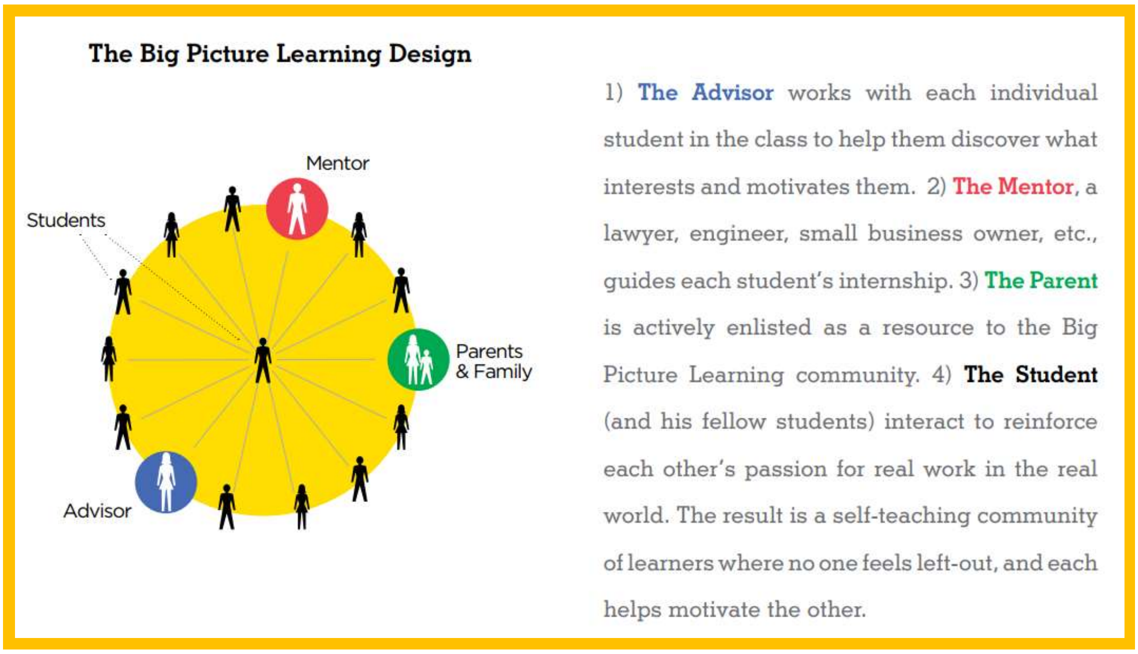

Figure 4.1: *The three basic principles of the Big Picture Learning Design: 1) Learning must be based on each student's interests and needs. 2) Curriculum must be relevant to the student and allow them to do real work in the real world. 3) Students' growth and abilities must be measured by the quality of their work and how it changes them.*

A very interesting initiative that is being implemented the last two decades in US is the Big Picture Learning initiative (http://www.bigpicture.org/). Big Picture Learning has worked to put students at the center of their own learning. Today, hundreds of Big Picture Learning network schools in the US and around the world work together and in their communities to reinvent and reshape education. Each student at a Big Picture Learning school is part of a small learning community of 15 students called an advisory. Each advisory is supported and led by an advisor, a teacher that works closely with the group of students and forms personalized relationships with each advisee. Each student works closely with his or her advisor to identify interests and personalize learning. The student as the center of learning truly engages and challenges the student, and makes learning authentic and relevant. Each student has an internship where he or she works closely with a mentor, learning in a real-world setting. Parents and families are actively involved in the learning process, helping to shape the student's learning plan and are enrolled as resources to the school community. The result is a student-centered learning design, where students are actively invested in their learning and are challenged to pursue their interests by a supportive community of educators, professionals, and family members (see Figure 4.1).

SEISMO-Lab initiative has also a plan to support further such schools' environment in this re-schooling process. Our strategy offers a support mechanism with two main axes, a) to define and deliver a holistic framework to support schools' innovation profiling and development towards the re-schooling process and b) to involve schools' communities in a pedagogical Plug and Play approach by introducing innovative approaches in the science curricula organization, by focusing on the development of key competences for both students and teachers.

5 Definition of Implementation Parameters

5.1 Resource-Based Learning and Use of Unique Open Educational Resources

5.1.1 Overview of Resource-based learning

During recent years, the definition, role and uses of recourses have undergone a metamorphosis. The changes have transformed how we think about resources, the distributed production of and access to digital resources, and how, when, and for what purposes we create and use them. The metamorphosis has been propelled by the exponential growth of information systems such as the internet and the web, and the ubiquitous presence of enabling technologies in classrooms, libraries museums, homes and communities. While increasing the numbers of and access to resources is energizing, realizing the educational potential of these breakthroughs may prove daunting. This is particularly true in formal learning settings (schools and universities) where current practices do not emphasize optimizing available resources or preparing individuals to learn in resource-rich environments. Teaching focuses on established curriculum goals, sequences, resources, and activities. 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"[17]. Several factors make RBL viable: 1) increased access to resources (print, electronic, people) 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 educators to create and implement learning environments of 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 organization to communication tools.
Scaffolds	Support that is faded over time. Includes conceptual, metacognitive, procedural and strategic scaffolds

Table 5.1 provides and overview of key characteristics. Each of the components will be briefly described in the following paragraphs.

5.1.3 Enabling contexts

Enabling contexts supply the situation or problem that orients learners to recognise or generate problems and frame their learning needs. By creating and enabling contexts, meaningful learning can occur with and through the resources provided or obtained. Enabling contexts can be imposed, induced or generated. Imposed contexts clarify expectations explicitly and guide

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

teacher and student strategies implicitly. Teachers may use determined objectives (e.g., National Curriculum). Induced contexts introduce a domain where problems or issues are situated, but not specific problems to be addressed. A typical scenario enables multiple problems or issues to be generated or studied based on different assumptions, topical relevance, and the context of use (see Figure 5.1). In generated contexts, specific problem contexts are not provided; rather, the learner establishes and interpretive context based on his or her unique needs and circumstances.

Figure 5.1: *The idea behind the organization of a Hackquake event was to involve students in an educational activity that would encourage them to use open research data and more precisely from 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 are "raw materials" that support learning, such as scientific databases and archives, textbooks, video, images, original source documents, visualizations, animations. Resources maybe provided by a more knowledgeable other (e.g., teacher) to assist others in extending or broadening knowledge or understanding. Resources may also be gathered by the learner as questions and/or needs arise. Given varying contexts of use, the utility of a resource may change dramatically from situation to situation. The web for example enables access to millions of resource documents, but their integrity and usefulness is judged by the individual and in accordance with the context of use. As resources increasingly become both relevant to the learners' need and accessible, they assume greater utility.

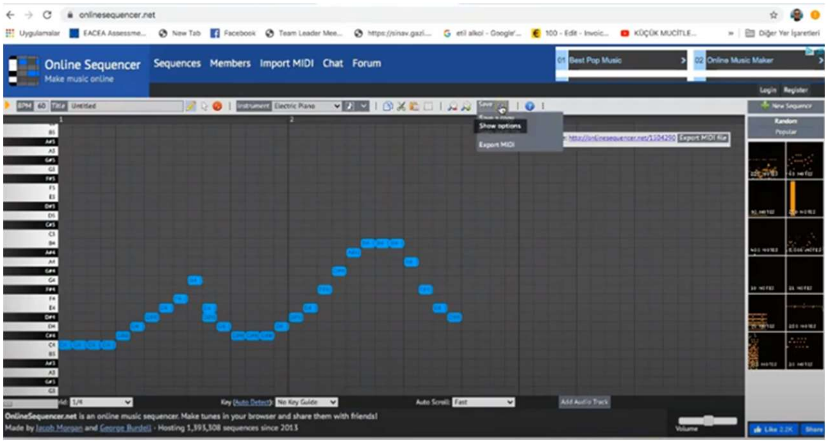

Figure 5.2: *Through sound editing applications, we can change the frequency of the seismic wave so that it can be heard by the human ears and with the help of a synthesizer software the seismic waveform is converted to musical notes and the sound of the earth is compiled.*

5.1.5 Tools

Tools enable learners to engage with and manipulate both resources and ideas. 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. For example, Inspiring Science Education provides an educational portal that offer access to numerous resources, activities and games and promotes the use of IBSE in different school settings (http://portalopendiscoveryspace.eu/ise). Collection tools, ranging from paper-based worksheets to high-end smartphones, aid in amassing resources and data for closer study. Students might use collection tools as they explore a learning space or after completing a tour.

Organisation tools are used to represent and define relationships among ideas, concepts, or "nodes". Like collection tools, organisation tools range from electronic to non-electronic devices. Concept mapping tools (e.g., www.insparation.com) are powerful devices that enable users to demonstrate relationships and links between and amongst ideas.

Integration tools help learners to relate in a new way with existing knowledge, which helps to both organise and integrate ideas. Integration tools might range from a word processing program to a web site. The depth and breath of what is represented by a single tool or set of tools vary according to the needs and abilities of the user. Generating tools as simple as a web site or as sophisticated as a modelling tool (e.g., SimEarth) help learners to create "objects" of understanding. Manipulation tools, which also range in their complexity, are used to explore beliefs and theories-in-action. Finally, communication tools (both synchronous and asynchronous) support efforts to initiate or sustain exchanges among learners, teachers, and experts.

5.1.6 Scaffolding

Scaffolding – support provided to assist learners and subsequently faded – varies with problem(s) encountered and the demands of the enabling context. Four types of scaffolding could be useful in exploring ways for the introduction of RBL in formal learning environments: conceptual, metacognitive, procedural and strategic.

- Conceptual scaffolds guide learners in what to consider, identifying knowledge related to a problem or making organisation readily apparent. Worksheets have traditionally been used in formal learning settings to help guide students as they explore a new concept or a topic. Conceptual scaffolding might be extended through communication tools in the form of leading questions or scenarios that set a context for the learners on a web site. For example inquiry approach makes considerable use of conceptual scaffolding to help guide learners as they explore new areas and build understanding.
- Metacognitive scaffolds support the underlying cognitive demands in RBL, helping learners to initiate, compare, and revise their approaches. Scenarios or cases are often used to focus and guide the learners as they explore and attempt to understand. Scenarios or cases can present ideas for learners to consider as well as checkpoints where learners examine their understanding, seeking to uncover what they do and do not know or understand.
- Procedural scaffolding aids the learner while navigating and emphasizes how to utilize a learning environment's features and functions. WebQuests, for example, use procedural scaffold extensively and have been used in a variety of contexts and content areas. According to Bernie Dodge, the primary creator, "WebQuests are designed to use learners' time well, to focus on using information rather than looking for it, and to support learners' thinking at the levels of analysis, synthesis and evaluation". By focusing on "how to", procedural scaffolds free up cognitive resources for other important learning activities (e.g., problem solving, higher-order thinking).

Finally, strategic scaffolds provide ways to analyze, plan and respond, such as identifying and selecting information, evaluating resources, and integrating knowledge and experience. Several models have been particularly useful in selecting and evaluating resources.

5.1.7 Opportunities and challenges with resource-based learning

RBL creates opportunities for the qualitative upgrade of both teaching and learning, heretofore unavailable, optimising the affordances of available and emerging technologies across a range of diverse settings.

- **RBL enables access to multitude of perspectives on a given phenomenon**. One of the most completing characteristics of RBL is the ability to view a variety of resources from a potentially unlimited number and range of perspectives. This is currently apparent in how textbooks are used in formal learning settings. Textbooks are often written from a particular perspective to promote a specific view of events and processes. Digital resources may also be written from a particular perspective, but ready access and easy cross-referencing enable extended access to more resources and therefore, multiple perspectives.
- **RBL can be implemented in a variety of contexts**. RBL approaches change both the nature and also the role of traditional resources (e.g., books), as well as the contexts in which they are used. RBL frameworks can be applied in multiple contexts, ranging from formal to informal, electronic to physical, specific to distributed locations, and at particular through unlimited time.
- **RBL facilitates learner-centred approaches**. While RBL tends to focus on individual approaches to learning versus teacher or large group approaches to learning, it is not inherently limited to one-to-one interactions. Students (individually, in small groups, or classes) can access a multitude of electronic, print and physical resources to assist with their learning in an RBL context. While the individual needs maybe addressed, it does not necessarily follow that student work is isolated or without guidance. Students may receive guidance or direction from an expert peer (e.g., a seismologist) via a communication tool. The key RBL focus is what the individual student's needs to facilitate growth in knowledge and understanding, not simply the group size or ratio; thus learner-centred approaches are not only supported but encouraged through RBL.
- **RBL cultivates key skills and competencies**. The skills and the competencies of the students in the Knowledge Society are different from those of generations past. With the explosion of knowledge, resources and challenges, learners need more strategic approaches to identify what is important and the depth of knowledge or skill needed in different contexts. Increasingly, learners need to discriminate when "knowing that" versus "understanding why" is appropriate or necessary. Given the prevalence of inaccurate, questionable, and contradictory evidence, assertions and propaganda expands geometrically. It is no longer sufficient for students to simply master what they encounter; they also need to demonstrate greater critical thinking, problem solving, reflection and self-direction than past generations. The use of open questions e.g., "how are particles accelerated in an electromagnetic field?" for example, stimulates an investigation rather than simple answer-seeking and engages the students in critical examination, reflection, and manipulation of multiple resources, thereby cultivating needed information seeking and evaluation skills.

The potential of RBL is considerable. Whereas conventional teaching approaches address known learning goals using well-organised sequences, resources, and activities, methods for supporting context-specific, user-centred learning have been slower to develop. Increasingly, individuals evaluate a vast number of digital resources located in expanding information repositories. Individuals must recognise and clarify their learning needs, develop strategies to address these needs, locate and access resources, evaluate their veracity and utility, modify approaches based on learning progress, and otherwise manage their teaching or learning. RBL enables teachers and learners to take advantage of the information systems we now have available, expending the resources they use to enhance the teaching and learning process.

5.2 Universal Design for Learning

5.2.1 Universal Design for Learning Guidelines

Universal Design for Learning (UDL) is a framework to improve and optimize teaching and learning for all people based on scientific insights into how humans learn. The SEISMO-Lab project will use the UDL Guidelines as a tool for the implementation of UDL in the design of the Educational Pathways. These guidelines offer a set of concrete suggestions that can be applied to any discipline or domain to ensure that all students can access and participate in meaningful, challenging learning opportunities. The framework is based on three key principles:

- Provide multiple means of **Engagement:** Affect represents a crucial element to learning, and **learners differ markedly in the ways in which they can be engaged or motivated to learn**. There are a variety of sources that can influence individual variation in affect including neurology, culture, personal relevance, subjectivity, and background knowledge, along with a variety of other factors. Some learners are highly engaged by spontaneity and novelty while others are disengaged, even frightened, by those aspects, preferring strict routine. Some learners might like to work alone, while others prefer to work with their peers. In reality, **there is not one means of engagement that will be optimal for all learners in all contexts**; providing multiple options for engagement is essential.
- Provide multiple means of **Representation: Learners differ in the ways that they perceive and comprehend information that is presented to them.** For example, those with sensory disabilities (e.g., blindness or deafness); learning disabilities (e.g., dyslexia); language or cultural differences, and so forth may all require different ways of approaching content. Others may simply grasp information quicker or more efficiently through visual or auditory means rather than printed text. Also learning, and transfer of learning, occurs when multiple representations are used, because they allow students to make connections within, as well as between, concepts. In short, **there is not one means of representation that will be optimal for all learners**; providing options for representation is essential.
- Provide multiple means of **Action & Expression: Learners differ in the ways that they can navigate a learning environment and express what they know.** For example, individuals with significant movement impairments (e.g., cerebral palsy), those who struggle with strategic and organizational abilities (executive function disorders), those who have language barriers, and so forth approach learning tasks very differently. Some may be able to express themselves well in written text but not speech, and vice versa. It should also be recognized that action and expression require a great deal of strategy, practice, and organization, and this is another area in which learners can differ. In reality, **there is not one means of action and expression that will be optimal for all learners**; providing options for action and expression is essential.

Table 5.2 presents the overall framework of the UDL Guidelines[18]. he UDL Guidelines are organized both horizontally and vertically. Vertically, the Guidelines are organized according to the three principles of UDL: engagement, representation, and action and expression. The principles are broken down into Guidelines, and each of these Guidelines have corresponding "checkpoints" that provide more detailed suggestions.

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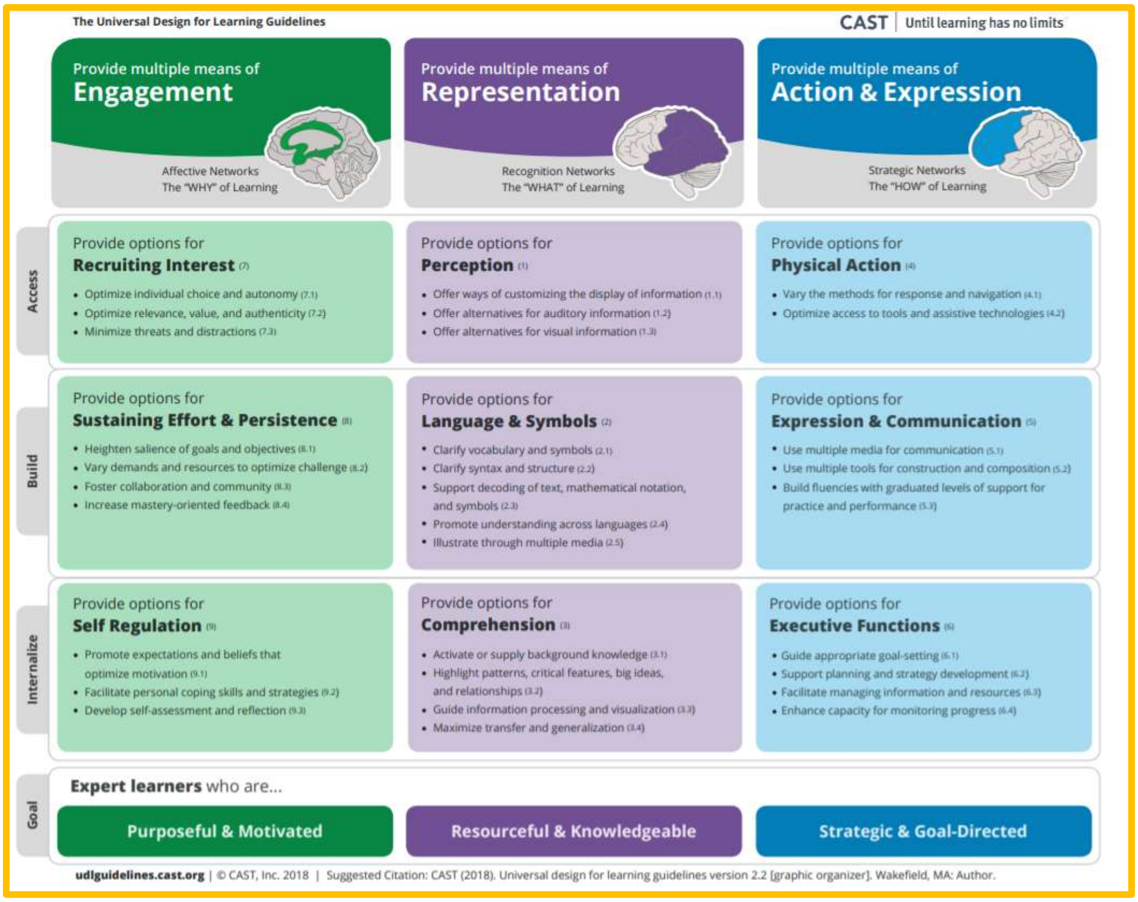
[18] CAST (2018). Universal Design for Learning Guidelines version 2.2. Retrieved from http://udlguidelines.cast.org

Table 5.2: *The Universal Design Guidelines*

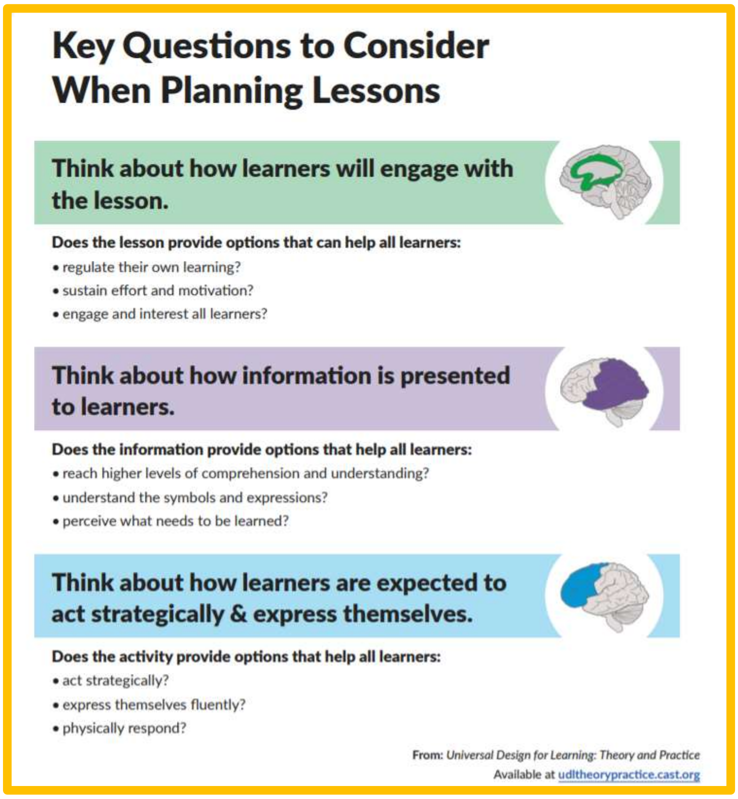


The Guidelines are also organized horizontally. The “access” row includes the guidelines that suggest ways to increase access to the learning goal by recruiting interest and by offering options for perception and physical action. The “build” row includes the guidelines that suggest ways to develop effort and persistence, language and symbols, and expression and communication. Finally, the “internalize” row includes the guidelines that suggest ways to empower learners through self-regulation, comprehension, and executive function. Taken together, the Guidelines lead to the **ultimate 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 Practice

The UDL Guidelines are not meant to be a “prescription” but a set of suggestions that can be applied to reduce barriers and maximize learning opportunities for all learners. **They can be mixed and matched according to specific learning goals** and can be applied to particular content areas and contexts. Following the UDL approach the SEISMO-Lab project will integrate the principles of inclusion in the proposed educational design of the SEISMO-Lab Demonstrators. UDL will help to meet this goal by providing a framework for understanding how to create curricula and activities that meets the needs of all students from the start as it provides multiple means of representation, options for language, mathematical expressions, and symbols, options for comprehension, multiple means of action and expression, options for physical action, options for expression and communication, options for executive functions, multiple means of engagement, options for recruiting interest, options for sustaining effort and persistence and options for self-regulation (e.g. facilitate personal coping skills and strategies). Universal design thus becomes integrated into core digital literacy skills that all students develop when implementing the SEISMO-Lab in the school settings. Starting from a universal design perspective, improvements in discussion boards and assessment instruments would focus on designs that support students in independent, successful task completion, while reducing clutter in the user interface that may create severe usability challenges for people with certain impairments. The confederated approach we propose for the proposed project is the key to progress in accessibility and universal design.

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



This approach would encourage the development of specialty tools that could potentially address the more difficult obstacles to accessibility. Incorporating universal design into the SEISMO-Lab will allow it to effectively address a wide range of accessibility needs and concerns, as well as encourage developers of the digital solutions to integrate accessibility as a core part of the design from the beginning. Table 5.3 presents the key issues to consider when the project team and the educational community will design the SEISMO-Lab Demonstrators.

6 The SEISMO-Lab Educational Scenarios Templates

Learning science (or learning about science) is not the same experience and does not carry to same meaning for everyone. In addition to the varying perceptions of science learning, its nature, objectives and workings, the diversity of science learning instances is also attributable to the variety of personal and institutional circumstances in which it may occur. Thus, the characterisation of science learning objects alone cannot generate adequate momentum for effective and sustainable exploitation of the rich content of digital repositories, unless this content can be accessed by the intended users in purpose-appropriate, meaningful ways. This challenge is addressed by the SEISMO-Lab. 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 school 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 characterize a way of learning (or a process) that promotes these competencies. The William and Flora Hewlett Foundation has 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 the development of 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

As a process, deeper learning is in alignment with the Partnership 21st Century Skills Framework, namely the 4C's (P21, 2011)[21]: Critical thinking and problem solving, Creative thinking and innovation, Collaboration, and Communication. The more skilled the learners become in learning how to apply these skills the more able they become in understanding deeper the academic content. As an outcome deeper learning results from the self-directed transfer of the 4C's to the student's understanding of a concept's meaning. Despite these different views all disciplinary standards documents that have been introduced since 2010 have a common reference point: deeper learning and the development of the 21st century skills do not happen separately from the understanding of knowledge in an academic discipline (mastery of academic

[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] P21. (2011). Partnership for 21st Century Skills (P21). Framework for 21st Century Learning. http://www.P21.org

content). As we prepare students for success in school today we are aware they will face a vastly different future. Our world changes rapidly and in a way that is different than what we have experienced in the past. Thus, the education system must be modified to serve the new generation of students and prepare them for success in the 21st century. Reports on the issue (Carnevale Smith, and Strohl, 2010 & Carnevale Smith, and Strohl 2013)[22] [23] show that a very small percent of future jobs will be available to high school graduates and dropouts and those jobs will be limited to mainly three low paying job classifications (sales and office support, blue-collar jobs, food and personal services). Moreover, the need of continuing education beyond the secondary level is highlighted in a report by the U.S. Center on Education and the Workforce report (Carnevale, Smith, and Strohl, 2010). Within the report it is stated that high school graduates (and dropouts) will be largely left behind in the future economy. Moreover, postsecondary education and training is not – as it used to be- the preferable path to middle and upper level pathway but "it is increasingly the only pathway". Despite the fact that deeper learning is referenced as an approach to help all students master academic content and have access to higher education, it is found (AIR, 2014) that it also prepares high-school graduates to perform well in workforce training programs associated with "*jobs that are likely to offer both a wage sufficient to support a small family and the potential for career advancement*" (p. 8).

Deeper learning supports the delivery of rich core content to learners in innovative ways that allow them to learn and then apply what they have learned. Rigorous core content is the heart of the learning process; true deeper learning is developing competencies that enable graduating high school students to be college and career ready and then make maximum use of their knowledge in life and work. Evidence also confirms that deeper learning environments positively influence not only student academic outcomes and but also student social-emotional factors (AIR, 2015)[24]. STEAM is much more than an acronym for a pedagogical model merging different domains. It is a transdisciplinary approach where learning is facilitated in an integrated way. In opposition to STEM that is now part of national strategies and education reforms the STEAM approach is being discussed, advocated but a strong policy around the concept is still far from reality in most countries. At the same time companies and research infrastructures are brining artists to be residents for their creativity and non-biased approach towards problem solving. This is not at all a new concept and in an interesting book related to the importance of the integration of STEAM in our lives we can find various examples where the integration of arts and the introduction of ethical and aesthetic insights are key to introducing innovation and modernization and a different understanding to complicated problems as for example the "sounds" of earth (see Figure 5.2 in the previous Chapter). The connection between science and arts is known for a long time and we have renowned scientists that used the arts as a mean not only for communication but also to enable their understanding of various phenomena (i.e. Leonardo da Vince, Galileo Galilei, etc.) It is largely accepted that Science can greatly benefit from insights coming from arts, from the creativity and flexibility it provides. STEAM is being discussed and "adopted" in several education systems but, its implementation is far from being a real interdisciplinary experience. In general, we find examples of Arts being associated to STEM efforts but not really being adopted with equal level of importance.

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[22] Carnevale, A., Smith, N., and Strohl. J. (2010). Help wanted: Projections of jobs and education requirements through 2018. Washington, DC: Center on Education and the Workforce, Georgetown University. Accessed 18.09.2022 at https://cew.georgetown.edu/wp-content/uploads/2014/12/HelpWanted.ExecutiveSummary.pdf

[23] Carnevale, A., Smith, N., and Strohl. J. (2013). Recovery: Job growth and education requirements through 2020. Washington, DC: Center on Education and the Workforce, Georgetown University. Accessed at 18.09.2022 https://cew.georgetown.edu/wp-content/uploads/2014/11/Recovery2020.FR_.Web_.pdf

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

6.2 The Deeper Learning classroom

This section aims to provide an idea of what deeper learning in STEAM classrooms looks like (in comparison with the current status in the participating countries). 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.

Applying Content Knowledge	Are subjects almost always siloed: math for 45 minutes, followed by science for 45, and then English for 45? Do you hear lots of bells for period changes? **OR** Are students learning through projects where teachers help students solve real-life problems? And are students learning how to apply learning in one subject to solve new problems, in school and out?
Thinking Critically	Are courses mainly organized around lectures and exams? **OR** Are students having to synthesize and analyse content to solve real-life problems, often through projects?
Working Collaboratively	Do students collaborate only occasionally and only in some classes, perhaps in a science lab, or just after school on homework? **OR** Are students, including those learning English or with special needs, regularly working together on real-world projects that require in-depth content knowledge?
Communicating Clearly	Is communications focused on what happens in English class, mainly mastering the rules of grammar and punctuation with an occasional essay? **OR** Are students embedding communications skills into everything they do in all their courses: speaking, listening, reading, and writing?
Learning Independently	Is the goal of the course fairly limited—to learn a specific body of knowledge and be assessed on it? **OR** Is there a broader context for learning, with students routinely setting short- and long-term goals, monitoring their progress, and reflecting on how they can improve?
Developing an Academic Mindset	Do students think they are either "smart" or "dumb"—and they can't do much to change their fate? Do they say things like, "I'm not a math person?" **OR** Do they believe that they have a "voice" and through hard work, perseverance, and similar traits they can learn to do better in school ... and elsewhere in their life?

Although it looks different from a typical classroom, the goal is that the students acquire at least the same content expertise (math functions, English grammar, the building blocks of chemistry and biology) as in a traditional classroom, but in more engaging ways. To help students address these challenging questions, teachers sometimes work across disciplines, so that math teachers are teaming with English teachers, graphic design teachers with chemistry teachers, and biology teachers with art teachers, for example. In addition to learning from textbooks, students are reading original open resources, watching videos, and learning how to conduct their own research, often on the Internet. Some of the first things you may notice in a deeper learning classroom are:

- Lots of peer-to-peer conversations about big issues that defy yes/no answers and ask students to think more analytically.
- Interdisciplinary topics, with some classes going longer than traditional class periods.
- Students working in groups, asking questions, and pushing each other to defend their answers.

According to PISA (2018)[25], school systems should rather emphasize on the mastery of processes, the understanding of concepts and the ability to function in different situations rather than the possession of specific knowledge. Education systems need to shift their focus from content to skills and start investing more on developing students' key competences and skills. Introducing interdisciplinary learning and adopting a STEM approach in school systems can be a very effective step towards creating more meaningful episodes of learning that focus heavily on skills, deepen conceptual understanding and achieve in introducing concepts within their real context.

The following discussion on STEM makes it clear why 21st century schools should move to STEM practices in order to meet their students' needs: "STEM education is not simply a new name for the traditional approach to teaching science and mathematics. Nor is it just the grafting of "technology" and "engineering" layers onto standard science and math curricula. STEM education removes the traditional barriers erected between the four disciplines, by integrating the four subjects into one cohesive means of teaching and learning. The engineering component puts emphasis on the process and design of solutions instead of the solutions themselves.

This approach allows students to explore math and science in a more personalized context, while helping them to develop the critical thinking skills that can be applied to all facets of their work and academic lives. Engineering is the method that students utilize for discovery, exploration, and problem solving. The technology component allows for a deeper understanding of the three other parts of STEM education. It allows students to apply what they have learned, utilizing computers with specialized and professional applications like Computer Assisted Design (CAD) and computer animation. These and other applications of technology allow students to explore STEM subjects in greater detail and in a practical manner" (Kennedy, 2014)[26].

As it is explicitly portrayed above, introducing activities that interweave technology and engineering with science and mathematics successfully can lead to an approach that covers the findings mentioned by Sawyer and can be an effective way of helping students to develop their 21st century skills by putting their acquired knowledge directly in use within a meaningful context that is directly linked to students' lives and the needs of contemporary societies. This will be strongly encouraged in the way the SEISMO-Lab framework is ultimately employed in order to help students imagine new ideas in STEAM education; to shift from "what is" to new possibilities of "what might be".

In this section we are presenting an image that offer a glimpse to a future in which students could explore words and cultures beyond their own both in distance and in time, as they were there. The image represents the deeper learning classroom and describe the activities that will be a norm in such an environment. In the framework of the SEISMO-Lab project the educational activities were developed having these images in mind.

Figure 6.1 (deeperlearning4all.org) represents the overall concept of the Deeper Learning Classroom that facilitates the transformation of the traditional classroom to an innovative environment that promotes the scientific exploration and supports the development of key skills for all students.

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

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

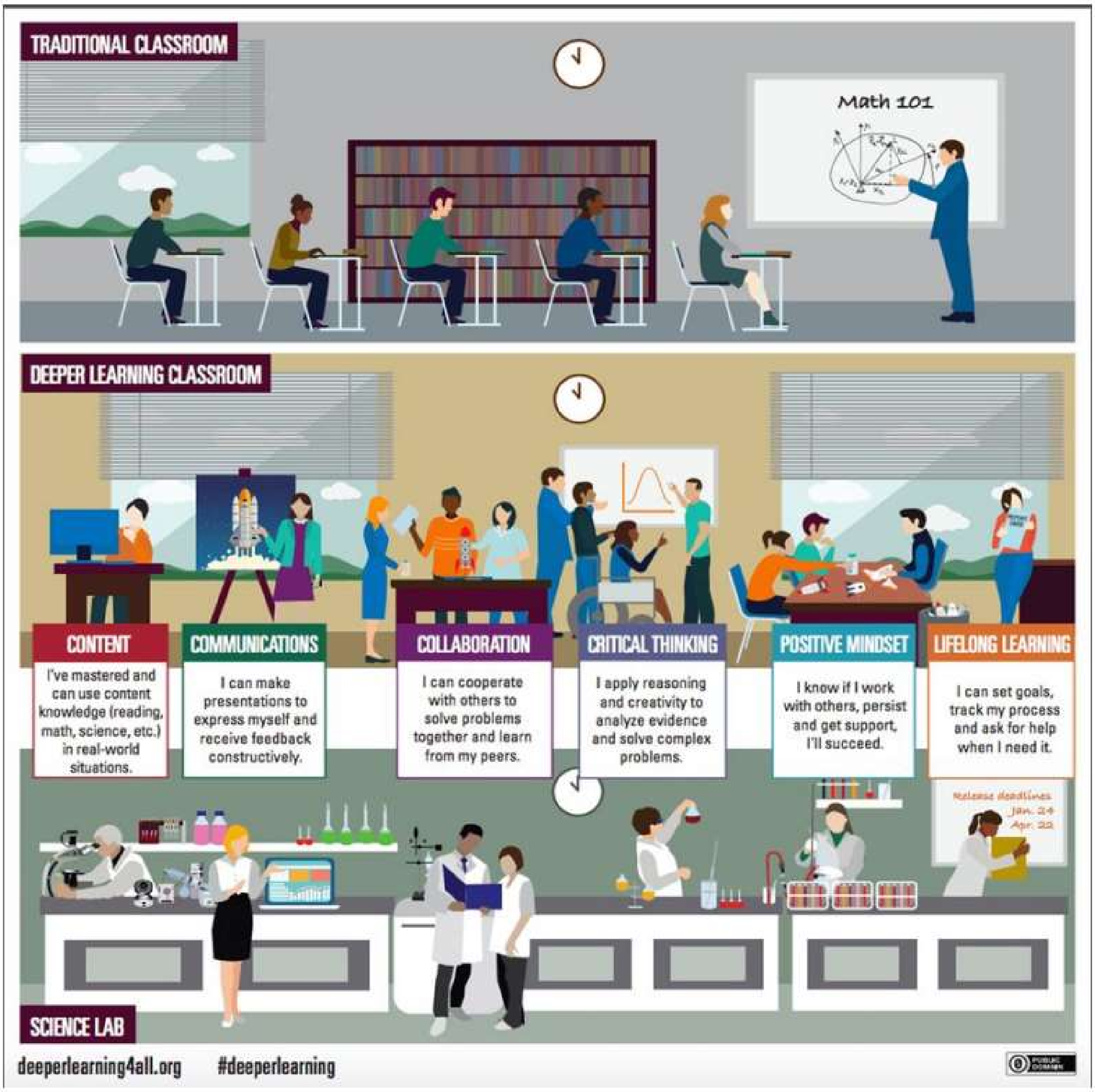


Figure 6.1: *The Deeper Learning Classroom facilitates that transformation of the traditional science classroom to a living laboratory that simulates the research work and introduces students to the scientific exploration. In such an environment, supported with the necessary resources, students are developing key skills like creative problem-solving competence, critical thinking, collaborative spirit and academic mindset while they are getting familiarized 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).*

In the following sections we are presenting a series of instructional models and approaches they could facilitate the realization of the Deeper Learning classroom. The portfolio of the proposed models includes different forms of inquiry learning that holds a great potential to reform current science education classrooms. The models are described in detail offering the opportunity to the educators to use them and design their own educational activities. We are describing in detail the inquiry-based model, the Learning Cycle, the project-based model, the 5E model, the and the Guided Research Model. Each approach has been organized in a series of sub-activities that have been designed to support the development of key students' abilities.

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) students 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. • Design and conduct scientific investigations. • Formulate and revise scientific explanations and models using logic and evidence • Recognise and analyze alternative explanations and models. **Attitudes** The students should be able to: • Acquire an appreciation for basic Science Education matters through the exposure in similar topics • Communicate and defend a scientific argument
4. Characteristics and Needs of Students	**Cognitive** The students have less than average knowledge level to mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of the 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**

Describing an Educational Scenario Template	
	The 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 • recognize and analyze alternative explanations and models • communicate and defend a scientific argument
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:	

Describing an Educational Scenario Template	
Phase 1: Question Eliciting Activities	**Exhibit curiosity** The 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. The 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** The 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.
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

Describing an Educational Scenario Template	
	• 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

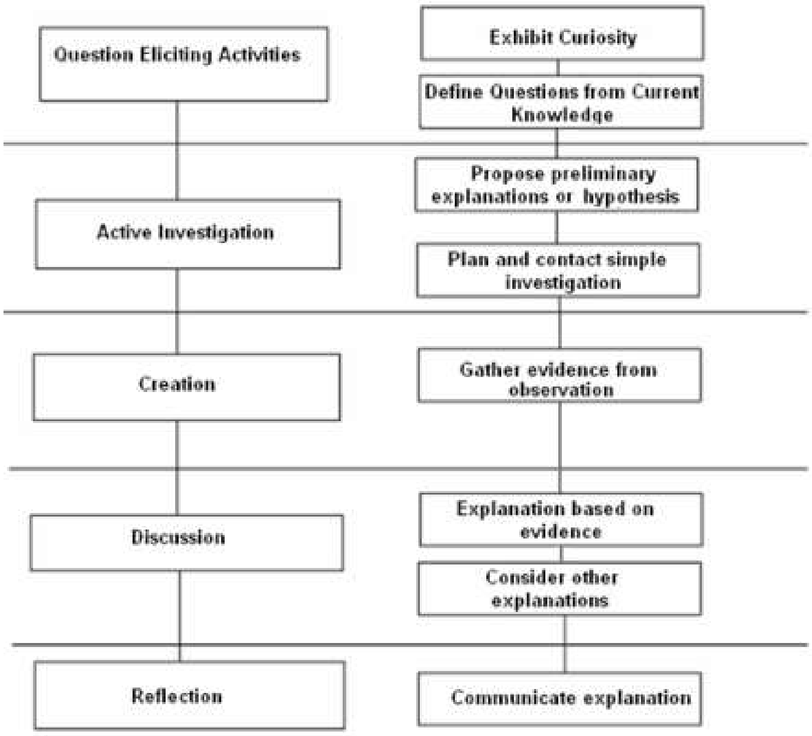


Figure 6.2: *Flow of Learning Activities for Inquiry Based Teaching*

6.3.3 Description of the Educational Scenario Template in Common Terms

6.3.3.1 Question Eliciting Activities

Table 6.2: *Question Eliciting Activities*

Phase 1 Question Eliciting Activities	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Exhibit Curiosity	Communicative Presenting	Information Handling Brainstorming	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer	problem statement
Define Questions from current knowledge	Communicative Debating	Information Handling Brainstorming	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer	other

6.3.3.2 Active Investigation

Table 6.3: *Active Investigation*

Phase 2 Active Investigation	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Propose preliminary explanations or hypotheses	Productive Synthesising	Adaptive Modeling	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer	problem statement
Plan and contact preliminary investigation	Experiential Exploring	Experiential Experiment	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer	simulation

6.3.3.3 Creation

Table6.4: *Creation*

Phase 3 Creation	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Gather evidence from observation	Experiential Experiencing	Adaptive Modeling	Who Group Based Medium Online Timing Synchronous	Facilitator, Group participant	Hardware Computer Software Database VLE	graph

6.3.3.4 Discussion

Table 6.5: *Discussion*

Phase 4 Discussion	Type	Technique	Interaction	Roles	Tools/Services	Resources
Explanation based on evidence	Information Handling Analysing	Communicative Structured debate	Who Class Based Medium Face to Face Timing Synchronous	Presenter, Group participant	Hardware Computer Software Text, Image, Audio or Video Viewer VLE	graph
Consider other explanations	Experiential Exploring	Communicative Arguing	Who Group Based Medium Online Timing Synchronous	Facilitator, Group participant	Hardware Computer Software Text, Image, Audio or Video Viewer VLE	other

6.3.3.5 Reflection

Table 6.6: *Reflection*

Phase 5 Reflection	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Communication of the explanation	Communicative Debating	Productive Report	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Group participant	Hardware Computer Software Text, Image, Audio or Video Viewer Models VLE	other

6.4 The Learning Cycle (Supporting Conceptual Change)

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) students 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 • Generalize or transfer ideas to other examples used as illustrations of the central concept • Apply previous knowledge **Attitudes** The learners should be able to: • Acquire an appreciation for basic Science Education matters through the exposure in similar topics • Develop interests, and initiate and maintain a curiosity toward the materials.
4. Characteristics and Needs of Learners	**Cognitive** The students have less than average knowledge level to mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of the 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**

Describing an Educational Scenario Template	
	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) 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

Describing an Educational Scenario Template	
	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.
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	**Generalization 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

Describing an Educational Scenario Template	
	• 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

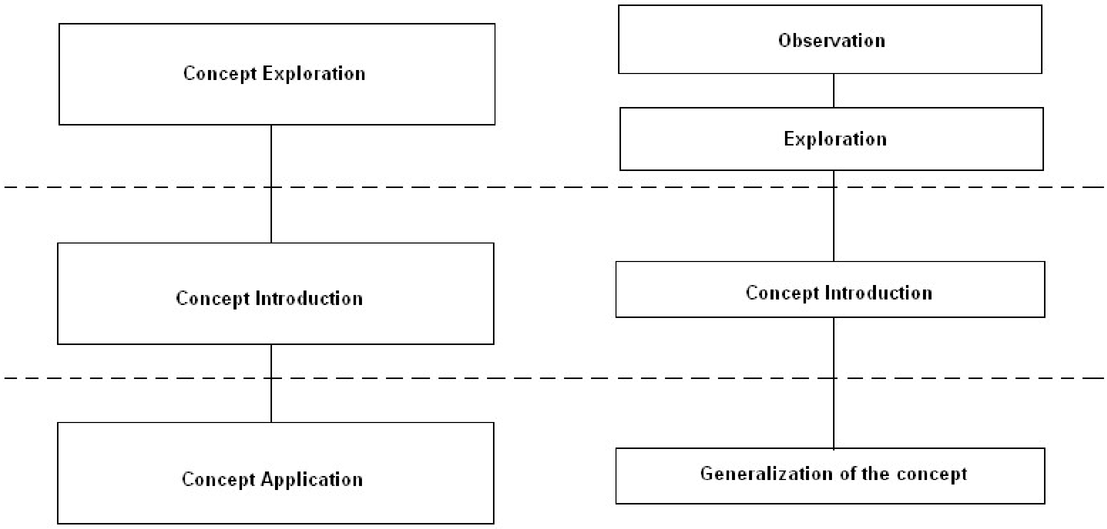


Figure 6.3: *Flow of Learning Activities for The Learning Cycle*

6.4.3 Description of the Educational Scenario Template in Common Terms

6.4.3.1 Concept Exploration

Table 6.6: *Concept Exploration*

Phase 1 Concept Exploration	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Observations	Experiential Experiencing	Experiential Experiment	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer, VLE	Other
Exploration	Experiential Exploring	Experiential Case Study	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer, VLE	Other

6.4.3.2 Concept Introduction

Table 6.9: *Concept Introduction*

Phase 2 Concept Introduction	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Concept Introduction	Communicative Presenting	Communicative Articulate reasoning	Who Class Based Medium Face to Face Timing Synchronous	Presenter, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer	Other

6.4.3.3 Concept Application

Table 6.10: *Concept Application*

Phase 3 Concept Application	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Generalization of the concept	Experiential Applying	Experiential Case Study	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer, Database	Other

6.5 The 5E Instructional Model (Constructivist 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 students engagement b) theoretical and abstract teaching c) textbook based instruction d) no demonstration infrastructure available e) students misconceptions f) lack of embedded assessment methods
3. Educational Scenario Template Objectives	**Knowledge** The students should be able to 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 • Generalize or transfer ideas to other examples used as illustrations of the central concept • Apply previous knowledge **Attitudes** The learners should be able to: • Acquire an appreciation for basic Science Education matters through the exposure in similar topics • Develop interests, and initiate and maintain a curiosity toward the materials
4. Characteristics and Needs of Learners	**Cognitive** The students have less than average knowledge level to mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of the 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.

Describing an Educational Scenario Template	
	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) 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: • Recognize students' current conceptions of objects, events, or phenomena. • Present situations slightly beyond the students' current conceptual understanding. One could also present the student 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, reorganize, elaborate, and change their initial concepts through interactions among the environment, classroom activities and experiences, and other individuals. Individual learners interpret

Describing an Educational Scenario Template	
	objects and phenomena and internalize 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.
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** The teacher organizes students' thinking toward the learning outcomes of current activities. These activities make connections to past and future activities.
Phase 2: Exploration	**Exploration – Observation**

Describing an Educational Scenario Template	
	Students have time in which they explore objects, 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 students knowledge** The teacher directs student attention to specific aspects of the engagement and exploration experiences. Students are asked to give their explanations. The teacher based on students' explanations clearly connects the explanations to experiences in the engagement and exploration phases. **Explaining concepts** The 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 results in better definition of the task as well as the identification and gathering of information that is necessary for successful completion of the task.
Phase 5: Evaluation	**Evaluate concepts, attitudes and skills** Students assess their understandings and abilities while teachers evaluate student progress toward achieving the educational objectives.
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**

Describing an Educational Scenario Template	
	• Identifies the learning task. • Facilitate and monitor interaction between students and instructional situations, materials, and/or courseware. • Direct students learning by clarifying misconceptions, providing vocabulary for concepts, giving examples of skills, modifying behaviours, and suggesting further learning experiences. • Provide an occasion for students to cooperate on activities, discuss their current understanding, and demonstrate their skills. • Use 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

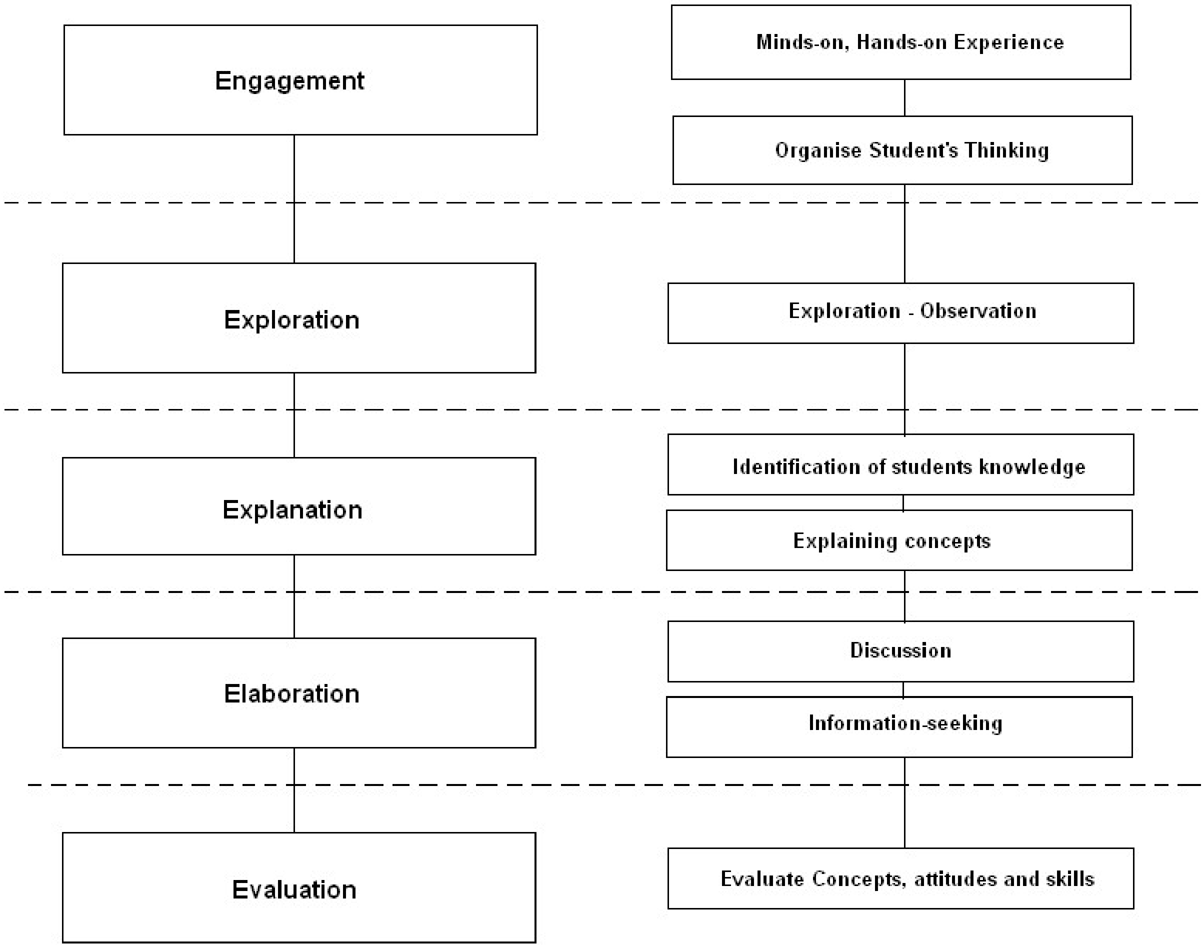


Figure 6.4: *Flow of Learning Activities for the 5E Instructional Model*

6.5.3 Description of the Educational Scenario Template in Common Terms

6.5.3.1 Engagement

Table 6.12: *Engagement*

Phase 1 Engagement	Type	Technique	Interaction	Roles	Tools/Services	Resources
Minds-On, Hands-On Experience	Experiential Investigating	Experiential Experiment	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer, VLE	other
Organise Student's Thinking	Information Handling Gathering	Information Handling Brainstorming	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer	other

6.5.3.2 Exploration

Table 6.13: *Exploration*

Phase 2 Exploration	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Exploration - Observation	Experiential Exploring	Experiential Practicing	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer, VLE	other

6.5.3.3 Explanation

Table 6.14: *Explanation*

Phase 3 Explanation	Type	Technique	Interaction	Roles	Tools/Services	Resources
Identification of students knowledge	Communicative Critiquing	Communicative Structured Debate	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer Software Database, VLE	other
Explaining Concepts	Communicative Presenting	Communicative Arguing	Who Class Based Medium Face to Face Timing Synchronous	Presenter, Individual Learner	Hardware Computer Software Database, VLE	other

6.5.3.4 Elaboration

Table 6.15: *Elaboration*

Phase 4 Elaboration	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Discussion	Communicative Discussing	Communicative Structured Debate	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer Software Text, Image, Audio or Video Viewer, VLE	other
Information Seeking	Communicative Presenting	Communicative Arguing	Who Group Based Medium Online Timing Synchronous	Facilitator, Group participant	Hardware Computer Software Text, Image, Audio or Video Viewer, VLE	other

6.5.3.5 Evaluation

Table 6.16: *Evaluation*

Phase 5 Evaluation	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Evaluate Concepts, Attitudes and Skills	Information Handling Analysing	Communicative Structured debate	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer Software Text, Image, Audio or Video Viewer, VLE	other

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 the learning-by-doing, where the activities in authentic context are strongly emphasized, which means the skills needed in working life, such as being able to work in teams, working in self-guided manner, and assessing of 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 artifacts • 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 • Recognize and analyze 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 less than average knowledge level to mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of the 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).

<table>
<tr><th colspan="2">Describing an Educational Scenario Template</th></tr>
<tr><td></td><td>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.</td></tr>
<tr><td>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</td><td>(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 of 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 have to be such that it involves learners in various kinds of activities that support the 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 is more in a role of the tutor facilitating the learning process (Henry, 2005).

(b)
It must be ensured that the required time for the project to be completed exists
It must be ensured that the appropriate cognitive background for the students exists
The teacher must prepare the topics for the students’ projects beforehand.
The teacher, who supports the learning process, should understand his role as a facilitator of the learning process. The teacher should not be in the experts' role trying to impose his knowledge over the topic or directing the activities of the learners, but let the learners to do their learning and decisions in projects.
Projects are central, not peripheral to the curriculum
Students must have access to PCs that are connected to the Internet.</td></tr>
</table>

Describing an Educational Scenario Template	
6. Learning Activities:	
Phase 1: Definition of the Project Goal	**Organize into Groups** The teacher divides the class into groups of students 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 and 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.
Phase 3: Doing the Project Work	**Collection of Information** Each group member collects information about the topics related to their project work. The teacher can support the students by pointing out with questions some 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 on those topics. **Synthesis of Information** After the students have collected the information, they synthesize 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

Describing an Educational Scenario Template	
7. Participating Roles:	**Student** • Actively participate 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 synthesizes information • Creates the final project • Presents the final project • Assesses the other groups **Teacher** • Prepare the project topics for the 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

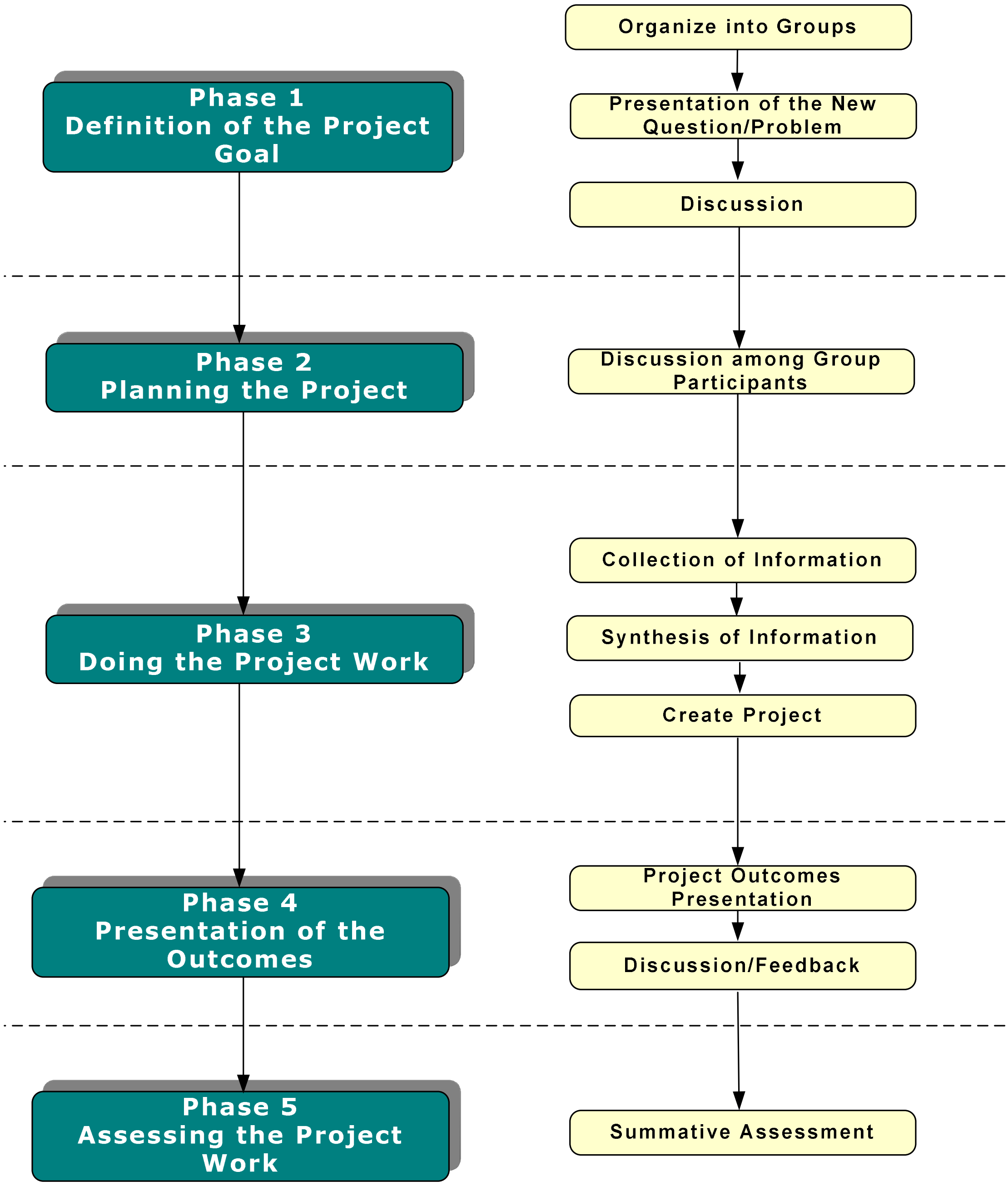


Figure 6.5: *Flow of Learning Activities*

6.6.3 Description of the Educational Scenario Template in Common Terms

6.6.3.1 Definition of the Project Goal

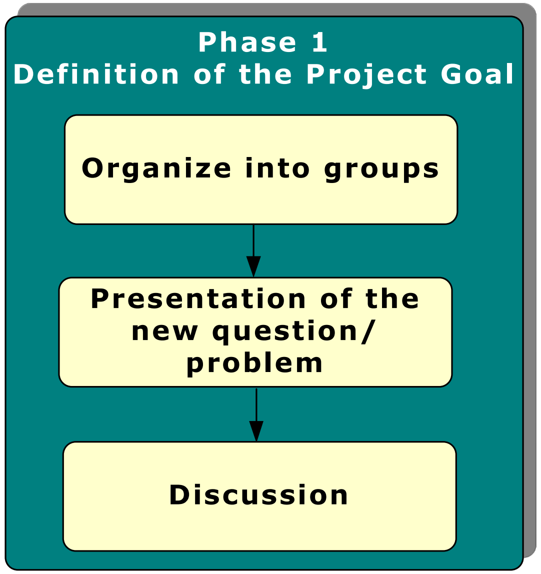


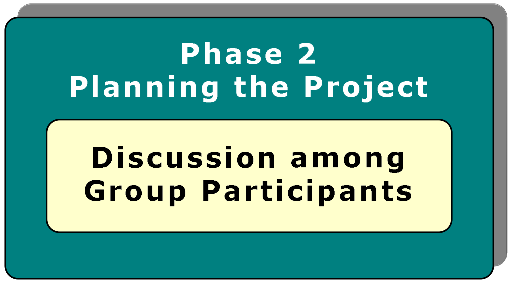
Table 6.18: *Definition of the Project Goal*

Type	Technique	Interaction	Roles	Tools/Services	Resources
Communicative – Presenting	Communicative – Negotiation	Who – Class Based Medium – Face to Face Timing – Synchronous	– Facilitator – Individual Learner	Hardware – Computer – Projector Software – Text, image, audio or video viewer	Slide
Information Handling – Analysing	Information Handling – Defining	Who – One to many Medium – Face to Face Timing – Synchronous	– Facilitator – Individual Learner	Hardware – Computer – Projector Software – Text, image, audio or video viewer	Problem Statement
Communicative – Discussing	Communicative – Coaching	Who – Class based Medium – Face to Face Timing – Synchronous	– Facilitator – Individual Learner	Hardware – Computer – Projector Software Text, image,	Other

				audio or video viewer	

6.6.3.2 Planning the Project

Table 6.19: *Planning the Project*



Type	Technique	Interaction	Roles	Tools/Services	Resources
Communicative – Discussing	Communicative – Debate	Who – Group based Medium – Face to Face Timing – Synchronous	– Group participant – Facilitator	Hardware – Computer – Projector Software – Text, image, audio or video viewer	Other

6.6.4 Doing the Project Work

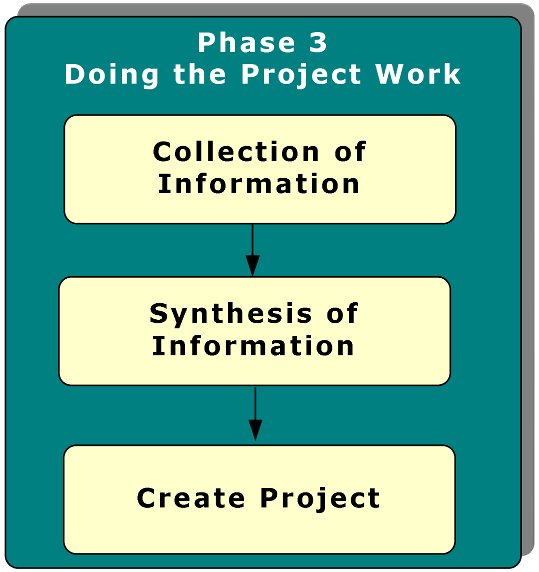


Table 6.20: *Doing the Project Work*

Type		Technique	Interaction	Roles	Tools/services	Resources
Inf. Handling – Gathering		Inf. Handling – Web Search	Who – Group based Medium – Online Timing – Synchronous	– Group participant – Facilitator	Hardware – Computer Software – Search engines – VLE	Graph
Productive – Synthesizing		Communicative – Arguing	Who – Group based Medium – Face to Face Timing – Synchronous	– Group participant – Facilitator	Hardware – Computer Software – Text, image, audio or video viewer	Other
Productive – Creating		Productive – Artifact	Who – Group based Medium – Face to Face Timing – Synchronous	– Group participant – Facilitator	Hardware – Computer Software – Word processor	Other

6.6.4.1 Presentation of the Outcomes

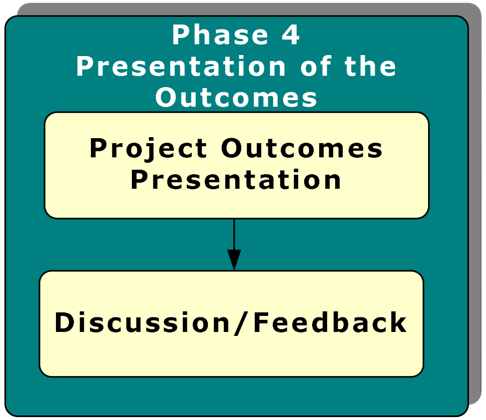


Table 6.21: *Presentation of the Outcomes*

Type	Technique	Interaction	Roles	Tools/services	Resources
Communicative – Presenting	Productive – Presentation	Who – Class based Medium – Face to Face Timing – Synchronous	– Group participant – Facilitator	Hardware – Computer – Projector Software – Text, image, audio or video viewer	Slide
Communicative – Critiquing	Communicative – Articulate reasoning	Who – Class based Medium – Face to Face Timing – Synchronous	– Group participant – Facilitator	Hardware – Computer – Projector Software – Text, image, audio or video viewer	Other

6.6.4.2 Assessing the Project Work

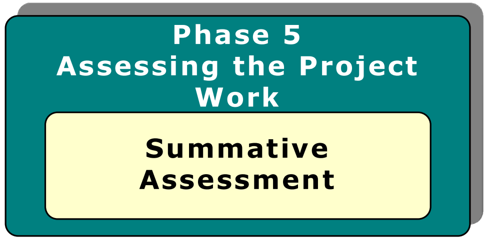


Table 6.22: *Assessing the Project Work*

Type	Technique	Interaction	Roles	Tools/services	Resources
Communicative – Critiquing	Communicative – Arguing	Who – Class based Medium – Face to Face Timing – Synchronous	– Group participant – Facilitator	Hardware – Computer – Projector Software – Text, image, audio or video viewer	Other

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) students 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 the exposure in similar topics
4. Characteristics and Needs of Learners	**Cognitive** The students have less than average knowledge level to mathematics and geometry. Limited knowledge of science subjects. **Psychosocial** Based on statistics less than 50% of the 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	Guided research teaching model of Schmidkunz & Lindemann (1992). The word research in the model description reveals its aim to help students explore

Describing an Educational Scenario Template	
(a) Description of the Educational Approach rationale (b) Parameters that guarantee the implementation of the Educational Approach	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.
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

Describing an Educational Scenario Template	
	• 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

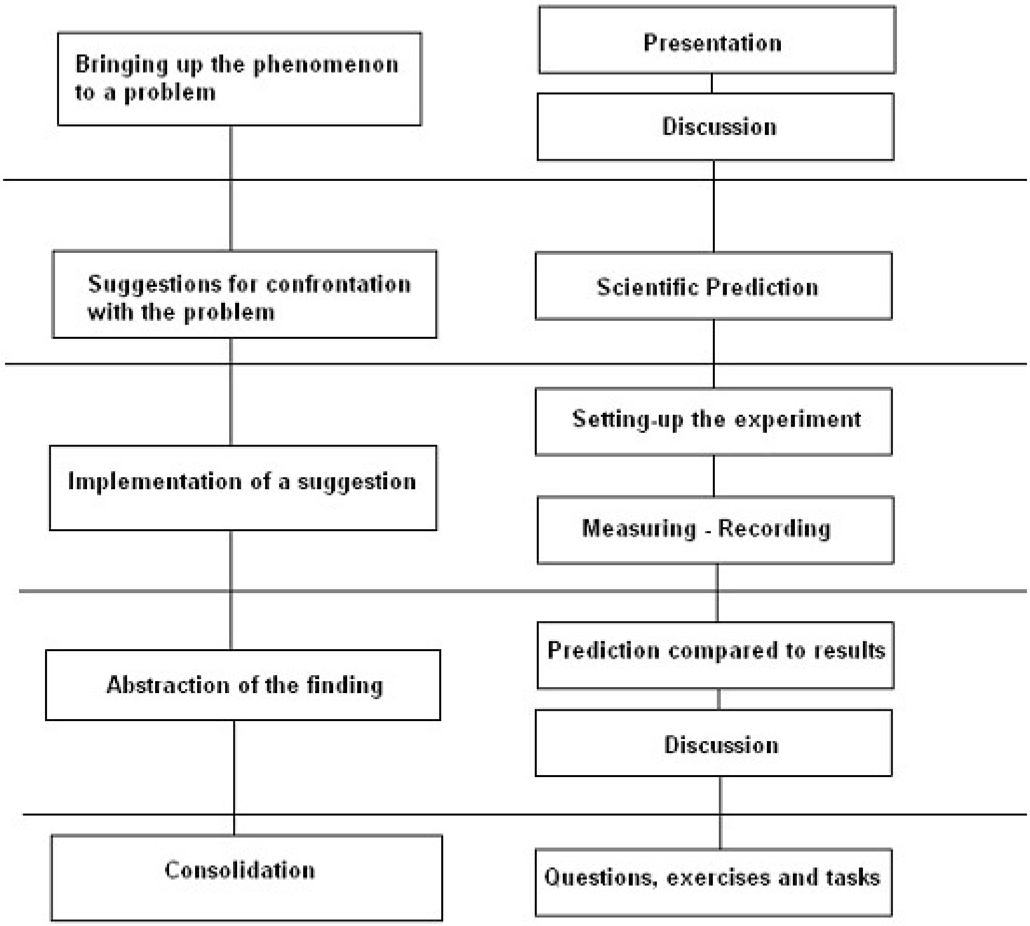


Figure 6.6: *Flow of Learning Activities for Guided Research Model*

6.7.3 Description of the Educational Scenario Template in Common Terms

6.7.3.1 Bringing up the phenomenon to a problem

Table 6.24: *Bringing up the phenomenon to a problem*

Phase 1 Bringing up the phenomenon to a problem	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Presentation of the concept/problem/theory	Communicative Presenting	Information Handling Defining	Who Class Based Medium Face to Face Timing Synchronous	Presenter, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer	Other
Presentation of alternative theories/ideas	Communicative Presenting	Information Handling Brainstorming	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer	Other
Discussion	Communicative Debating	Communicative Discussion	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer	Other

6.7.3.2 Suggestions for confrontation with the problem

Table 6.25: *Suggestions for confrontation with the problem*

Phase 2 Suggestions for confrontation with the problem	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Scientific Prediction	Productive Synthesising	Adaptive Modeling	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer, Projector Software Text, image, audio or video viewer	Other

6.7.3.3 Implementation of a suggestion

Table 6.26: *Implementation of a suggestion*

Phase 3 Implementation of a suggestion	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Setting up the experiment	Experiential Investigating	Experiential Experiment	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer Software Database, VLE	Other
Measuring-Recording	Experiential Experiencing	Productive Product	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer Software Database, VLE	Other

6.7.3.4 Abstraction of the finding

Table 6.27: *Abstraction of the finding*

Phase 4 Abstraction of the finding	**Type**	**Technique**	**Interaction**	**Roles**	**Tools/Services**	**Resources**
Prediction compared to results	Information Handling Analysing	Communicative Debate	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer Software Text, Image, Audio or Video Viewer, VLE	Other
Discussion	Communicative Debating	Communicative Discussion	Who Class Based Medium Face to Face Timing	Facilitator, Individual Learner	Hardware Computer Software	Other

			Synchronous		Text, Image, Audio or Video Viewer, VLE	

6.7.3.5 Consolidation

Table 6.28: *Consolidation*

Phase 5 Consolidation	Type	Technique	Interaction	Roles	Tools/Services	Resources
Questions, exercises and tasks	Information Handling Analysing	Communicative Arguing	Who Class Based Medium Face to Face Timing Synchronous	Facilitator, Individual Learner	Hardware Computer Software Text, Image, Audio or Video Viewer, VLE	Other

7 References for the Educational Scenarios Templates

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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: Synthesizing	Synthesizing 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: Modeling	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 learning process

Annex		
	Presenter	The teachers 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 were 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, experiment, table, self assessment, exercise, questionnaire, exam