Pedagogical Framework

(Intellectual Output 01)

Schools Study Earthquakes

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1. Introduction

The School Study Earthquakes (SSE) project aims to increase students' interest in scientific processes, influence their awareness of how earthquakes affect their life, as well as assisting them to develop key skills, such as analysis and problem solving skills through the study of seismology. Exploiting the innate curiosity of students about natural phenomena enables lifelong learning (National Research Council, 2000). In order to achieve this goal, teacher's role is significant. Inquiry – based learning (IBL) is an effective method that connects preexisting representations with the accepted scientific knowledge and promotes scientific literacy (Panasan & Nuangchalerm, 2010). Due to the continuous growth of research interest in the improvement of science education through IBL, competences are required from teachers in order to design science lessons (Alake-Tuenter, Biemans, Tobi & Mulder, 2013; Maaß & Doorman, 2013). Therefore, the Pedagogical Framework that is a requirement of Intellectual Output 1 (O1) of the present project will serve as a guide in assisting teachers in planning and implementing inquiry lessons and activities within their science classrooms. The framework is built around three components, which are as follows:

a) Project-mapping with the school curricula of the national educational systems of the participating countries
b) Determining the educational and pedagogical role of the teachers leading the students' teams involved
c) Further sound concepts and tools for the development of additional inquiry based learning scenarios in order to enhance the learning experience of students in the school teams participating

The Pedagogical Framework of the SSE project that is presented is flexible, widely applied and offers teachers the main structure for designing learning and evaluation processes for their students (Pedaste et.al, 2015).

2. Definition of inquiry – based learning

The National Research Council (1996) defines inquiry as the:

> Diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (p.23)

As a construct of science and science education community, inquiry refers to methods that scientists employ, the pedagogical approach that teachers follow and the cognitive development of students (Minner, Levy & Century, 2010). Inquiry contains not only the engagement with scientific practices, but also the understanding of the process and dissemination of scientific knowledge (NRC, 2000). As a process, IBL occurs when there is curiosity and need to solve a problem that the learner notices and should model scientific approaches that resemble scientists inquiry habits (National Science Foundation, 2000).

Ideally, IBL aims in assisting students to gain, in a progressive fashion, inquiry competences (Bell, Smetana & Binns, 2005) necessary for daily life and for performing scientific investigations independently. This discovery process is divided into phases and sub – phases in order to guide students' scientific thinking more effectively and to ensure that they are engaged into authentic scientific processes. It should be noted that for the purpose of this project, the focus for developing this pedagogical framework relies both on learners' and teachers' role. An analytical description of the inquiry phases is provided in section 5.

3. Theoretical underpinnings of inquiry – based learning

IBL approach is built on the philosophy of constructivism, which considers that students and adults learn by active development and structuring of knowledge based on everyday life (Driver, Asoko, Leach, Mortimer & Scott, 1994). Knowledge is constructed by individuals with the embodiment and/or replacement of prior representations via active participation in the learning process (Minner, Levy & Century, 2010). Therefore, students' existing knowledge about scientific concepts plays a central role in teaching (Limón, 2001) and the fusion of experience and new knowledge is vital for cognitive development (Powell& Kalina, 2009).

As Keys and Bryan (2001) state, cognitive constructivism does not really take into account the social contexts that influence knowledge, and therefore a social constructivist framework is needed. Social constructivism considers learning as a social process that takes into account the learners interaction with the learning environment and the understanding of the social context (Kim, 2001). A social constructivist teacher utilizes the classroom environment and culture to engage learning with students' experiences and interests so that they become competent constructors of world awareness (Oldfather, West, White, & Wilmarth, 1999).

Acknowledging this, inquiry aims to change students misconceptions about a scientific concept by providing them with evidence that conflict with the scientifically accepted within social interaction (Keys & Bryan, 2001). Both constructivism and social constructivism value inquiry as a method for creating an effective environment with the students building on their own existing knowledge and the teacher guiding them through that process (Powell& Kalina, 2009).

4. The role of inquiry and inquiry – based learning

IBL aims to provide students with experiences from the physical world that contribute to the development of skills, conceptual understanding and positive attitudes towards science. If there is no active engagement with processes and concepts of science in a science classroom, then students will not truly appreciate science as a way to understand the natural world (Brunsell, 2008). Prior research indicates that inquiry-based instructional practices are more conductive than other forms of instruction in promoting conceptual understanding (Minner, Levy, & Century, 2010). Students that experience inquiry can better apprehend science and its practices (Edelson, Gordin & Pea, 1999).

Inquiry is firmly connected to the acquisition of scientific skills. The research of Gerber, Cavallo and Marek (2001) revealed that students in inquiry classrooms have or develop greater scientific reasoning abilities than students in formal traditional classrooms. IBL is a flexible, student centered process which exploits authentic scientific methods to develop necessary future skills for the modern student such as collaboration, adaptability, imagination and critical analysis of information (Marks, 2013). Students engage in activities of formulating questions that can be answered through their own research and communication with others (Wu & Hsieh, 2006). According to the National Science Foundation (2000), inquiry provides information about the developmental stage of students, enables them to communicate effectively in a social context and to make their own decisions based on information received from their inquiry outcomes.

5. Phases and sub – phases of inquiry activities

IBL is an educational, flexible strategy with phases that are often organized in a cycle and divided into sub – phases with logical connections depending on the context under investigation (Pedaste et al., 2015). This framework entails five general phases (Orientation, Conceptualization, Investigation, Conclusion and Discussion) and seven sub-phases (Questioning, Hypothesis Generation, Exploration, Experimentation, Data Interpretation, Reflection, and Communication). It can be used by teachers in order to conceptualize a structured way to implement inquiry activities in their science classroom.

IBL is not a linear procedure (see Figure 1) and learners should be involved with various forms of inquiry, going through different combinations of the phases, not all of them necessarily (Wu & Hsieh, 2006; Pedaste et al., 2015; Pedaste & Sarapuu, 2014). For example, if the data analysis is not satisfactory enough, students can return to the conceptualization phase and reconsider their question and/or their experimental design. When students come to a conclusion, new questions can be generated and the process starts again in a progressive fashion. A description of the processes that each phase encompasses is provided below and the connections between these processes are presented in Figure 1 (Pedaste et al., 2015).

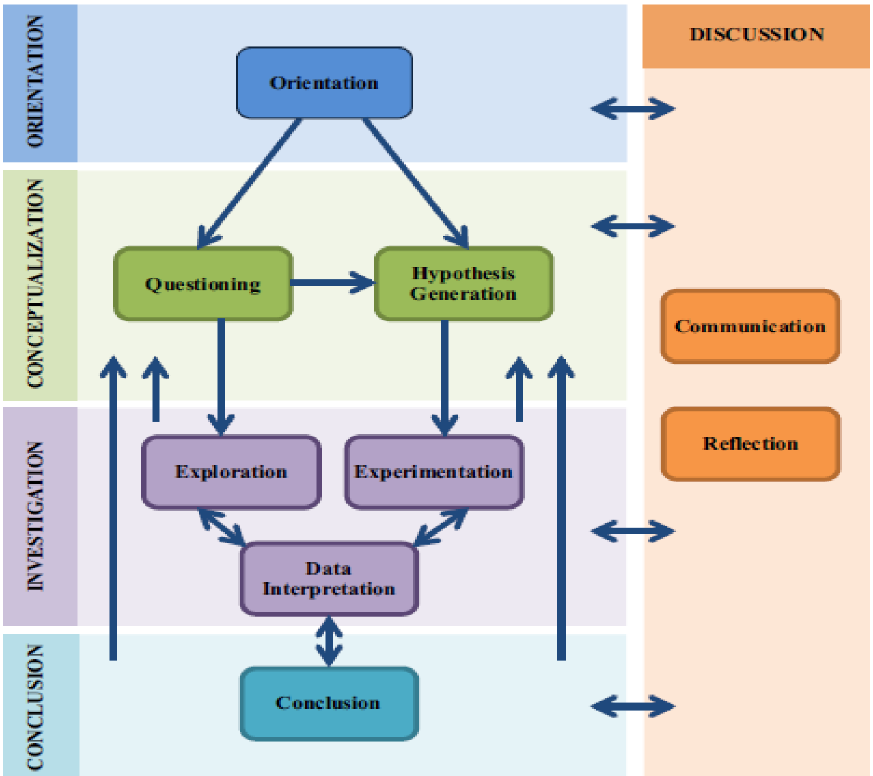

Figure 1. Phases, and sub – phases of Inquiry – based learning and their relations. Excerpted from ''Phases of inquiry-based learning: Definitions and the inquiry cycle'' by Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A., Kamp, E. (2015).

5.1. Orientation

As Mark (2012) states, “student curiosity is at the center of the process” (p. 22). Orientation is the phase where the identification of the problem occurs (Pedaste & Sarapuu, 2014). The topic to be investigated is presented and interest about a problematic situation that can be answered with inquiry is stimulated (Pedaste & Sarapuu, 2014; Pedaste et al., 2015). The topic under investigation must be relevant to students’ daily life, interests and prior knowledge.

Teacher’s role: *Encourages students to express ideas, prior knowledge and questions about the topic, while promoting interaction and communication between them. For example, students can create concept maps of what they know, do not know or want to know about the topic under investigation. These kinds of activities can also be useful for the next phases of inquiry.*

5.2. Conceptualization

Conceptualization refers to the understanding of the concept, which relates to the problematic situation presented in the previous phase. It is divided in two sub phases (questioning and hypothesis generation) that lead the learner to the investigation phase (Pedaste et al., 2015).

Teacher’s role*: Helps students understand how they can formulate questions and/or hypotheses that can lead to an investigation. If students are not familiar with the questioning and hypothesis generation sub – phases, the teacher can choose a structured type of inquiry at first and then progress in more open types of inquiry in order to provide the appropriate guidance (see section 6).*

5.2.1. Questioning

Questions are formulated in order to design an investigation that produces answers (Marks, 2013). As this skill is developed through inquiry, students can gradually understand which question can lead to investigation and which one is more generative and might lead to different or richer processes (NSF, 2000).

5.2.2. Hypothesis Generation

A hypothesis is generated through providing explanations of how the identified variables relate (Pedaste et al., 2015). It explains how and why phenomenon functions based on former experiences and prior knowledge (NSF, 2000).

5.3. Investigation

Investigation is the phase where students collect evidence in order to answer their questions and/or test their hypothesis (NSF, 2000) and includes the sub – phases of exploration, experimentation, and data interpretation.

<u>Teacher's role</u>: *Provides materials that the students might need and keeps them on track so that the process they choose to follow is a process that answers the investigative question. Students should determine what constitutes evidence and collect it. If they are not familiar with this process, a structured type of inquiry can be chosen (see section 6). The teacher can provide or encourage students to create means (e.g. tables, charts etc.) that can help them organize, classify and analyze the data.*

5.3.1. Exploration

Exploration is an open process which generates mostly data concerning the identification of a relation between the variables. It is chosen typically when the question that was formed in the previous phase was generative, because students do not have a specific idea of what to explore or how the identified variables relate to each other (Pedaste et al., 2015).

5.3.2. Experimentation

Experimentation includes the design (e.g. choosing the materials and means to measure) and performing of experiments taking into consideration the variables that need to change, remain constant and be measured. The product of this sub – phase are data or evidence that can be used later on for analysis and interpretation.

5.3.3. Data Interpretation

According to the NSF (2000), data interpretation "includes finding a pattern of effects and synthesizing a variety of information" (p. 57). Depending on the concept under investigation and the inquiry procedures that were chosen, finding relations between the variables is sometimes the key for getting the desired outcome (answering the investigative question). Organizing and classifying the data (with graphs, charts, tables, pictures etc.) can benefit this process.

5.4. Conclusion

In this phase students draw conclusions based on the investigative question and the interpretation of the data.

<u>Teacher's role</u>: *During this phase, a comparison between the interpreted data and the predictions and initial ideas (that students expressed during the orientation phase) can be stimulated. This process can also lead to new hypotheses and questions about the topic under investigation (as shown in Figure 1).*

5.5. Discussion

During the discussion phase students articulate their findings through communicating them to others and/or reflecting upon all or some of the stages of inquiry during the process or by the end of it (Pedaste et al., 2015).

<u>Teacher's role</u>: *Encourages collaboration so that students can present their findings and ideas, provide arguments and give feedback to others. If they are not familiar with these practices, the teacher can provide guidelines that will help them to communicate during all the phases of inquiry.*

5.5.1. Communication

Communication includes discussion with others and representation of results in a manner that is understandable to all (NSF, 2000). It can be applied to a single phase or the whole cycle of inquiry and is usually an external process (Pedaste et al., 2015).

5.5.2. Reflection

In this sub – phase students reflect on their work, their results and the concept under investigation. Reflection can even give rise to new thoughts regarding the inquiry cycle or a single phase (Marks, 2013).

6. Types of inquiry

The types of inquiry vary so that students are actively involved in the process to the extent that they are competent and able to do so. The type of inquiry a teacher may choose to follow is highly depended on the objectives of the lesson, the age of the students, their previous involvement with inquiry and the scientific skills they have already acquired. As shown in Figure 2, the more responsibility the student has, the less direction is provided and more open the inquiry becomes (NRC, 2000).

Figure 2. Types of inquiry and their features regarding questions, evidence, explanations, connection of the explanations to scientific knowledge and communication. Adapted from Inquiry and the National Science Education Standards, NRC (2000) p. 29

Learner self - direction →

← Teachers' guidance

Essential Features	Structured	Mixed	Guided	Open
1. Learner engages in scientifically oriented **questions**	**engages in question provided by teacher, materials, or other source**	**sharpens or clarifies question provided by teacher, materials, or other source**	**selects among questions, poses new questions**	**poses a question**
2. Learner gives priority to **evidence** in responding to questions	**given data and told how to analyze**	**given data and asked to analyze**	**directed to collect certain data**	**determines what constitutes evidence and collects it**
3. Learner formulates **explanations** from evidence	**provided with evidence and how to use evidence to formulate explanation**	**given possible ways to use evidence to formulate explanation**	**guided in process of formulating explanations from evidence**	**formulates explanation after summarizing evidence**
4. Learner connects **explanations** to scientific knowledge		**given possible connections**	**directed toward areas and sources of scientific knowledge**	**independently examines other resources and forms the links to explanations**
5. Learner **communicates** and **justifies** explanations	**given steps and procedures for communication**	**provided broad guidelines to use sharpen communication**	**coached in development of communication**	**forms reasonable and logical argument to communicate explanations**

The variations of inquiry types concern the increasing or decreasing involvement of the teacher and student in the process. Structured inquiry is directed from the teacher so that students reach a specific result (Colburn, 2000), whereas in mixed inquiry students are more involved during an investigation with the teacher guidance still being the most dominant. These forms of inquiry usually are chosen when students are first introduced to inquiry practices and when there is a focus in the development of a specific skill or concept. Open inquiry provides more opportunities for developing scientific skills (NRC, 2000), given that during open inquiry the students work directly with the materials and practices in a way that resembles authentic scientific approaches.

For example, if students lack previous experiences with designing investigations and collecting data, a more structured or guided form of inquiry should be chosen. When students acquire the skills needed, they can progress to more open inquiry activities. Students should at some point participate in all the forms of inquiry (NRC, 2000), while gradually moving from one form of inquiry to another with the simultaneous progression of complexity and self – direction (Bell, Smetana & Binns, 2005).

7. Combination of physical & virtual manipulatives within the context of the SSE project

Educational material and learning opportunities that support and promote IBL can be developed with the use of physical and/or virtual manipulatives. The term *virtual manipulatives* refers to the use of computer programs (e.g. simulations, virtual labs) with the interaction of the keyboard and the mouse with the computer screen, whereas the term *physical manipulatives* refers to the use of real materials (Zacharia, Loizou & Papaevripidou, 2012).

Both manipulatives can be effective depending on the context and the way they are used. On the one hand, physical manipulatives promote the designing of investigations and the use of real scientific devices that can lead to a better understanding of a phenomenon (Smith & Puntambekar, 2010). On the other hand, virtual manipulatives can ensure efficiency, minimization of errors, safety and reality adaption (De Jong, Linn, & Zacharia, 2013). The use of virtual manipulatives has received increased attention for supporting inquiry in science classrooms and promoting learning (Edelson, Gordin & Pea, 1999). When a scientific concept is not directly observable, such as the concept of earthquakes, technology offers opportunities for experimentation and exploration of the phenomenon.

Each manipulative has its own affordances that affect the process and the outcome, but both can promote IBL (Zacharia & Olympiou, 2011). During the SSE project a combination of the two manipulatives is anticipated for implementation in order to provide a variety of experiences that promote scientific literacy. The project aims at a close collaboration with established EU funded educational projects on inquiry learning at schools, such as Inspiring Science Education (http://www.inspiringscience.eu), Global Online Labs for Inquiry Learning (http://www.go-lab-project.eu) and Ark of Inquiry (http://www.arkofinquiry.eu).

During the SSE project a collection of online and offline educational resources will be utilized to facilitate the inquiry phases of investigation and exploration and promote virtual and physical experimentation. These include scientific simulations, animations, repositories of real earthquake data, specialized software for data analysis and processing in combination with scientific instruments, such as educational seismographs or operational real-time seismometers installed or distributed to partners and schools by NOA within the framework of the SSE project. More detailed information, guidelines, user's manuals and examples of usage will be included in the Intellectual Outputs 3 and 4, Implementation Guide and Seismology Handbook, respectively.

8. Three - component pedagogical framework

In the SSE project, a pedagogical framework is suggested for development to serve as a guide in assisting teachers in planning and implementing inquiry lessons and activities within their science classrooms. The framework is built around three components, which are as follows:

a) Project-mapping with the school curricula of the national educational systems of the participating countries
b) Determining the educational and pedagogical role of the teachers leading the students' teams involved
c) Further sound concepts and tools for the development of additional inquiry based learning scenarios in order to enhance the learning experience of students in the school teams participating

An elaboration on each of the three components of the Pedagogical Framework is provided in the subsequent sections.

8.1. Project-mapping with the school curricula of the national educational systems of the participating countries

The five countries that participate in the SSE project are Bulgaria, Cyprus, Greece, Italy and Turkey. These countries have been chosen because of the frequent seismic activity and the past experience in such physical events. Therefore, the concept of earthquakes is useful, interesting and essential for the communities and schools of these countries. Each country has its own national educational system that defines the school curricula and hence the teaching of the concept of earthquakes. The basic information (school level, age, grade, teaching approach, competences, types of activities and evaluation) regarding each country's curricula for the concept of earthquakes is provided in the five Tables beneath.

The teaching approach that is indicated as optimal in these five countries is the investigation oriented approach. The concept competences are correlated with this approach and depend on the school level and age of students. The concept competences in all countries

Mapping the earthquakes with the national curriculum of Bulgaria

curriculum units focus on the generation of knowledge about the effects of an earthquake and its impact/risk in relation to their country. Also, some countries objectives deal with matters of the generation of an earthquake (e.g. Cyprus and Greece) and/or about the means that are used in seismology (e.g. Turkey and Italy). The skill competences of all countries refer to the promotion of scientific literacy. The types of evaluation that are indicated from the national science curriculum of each country are formative and final evaluation through various means is suggested.

Based on the analysis performed from the information provided by each participating country, the concept of earthquakes has a frivolous place in the national curricula and it is usually not addressed interdisciplinary. The concept requires knowledge from different scientific areas and can be therefore utilized in various contexts and studied as a STEM (Science – Technology – Engineering - Mathematics) subject. The integration of these approaches improves students learning and attracts their interest (Becker& Park, 2011; Sanders, 2009).

Domain:	Environment (for Primary school), Geography (for High school)	
Sub – domain:	Disaster protection (for Primary school and High school)	
School level: Primary school, High school	**Age:** 8 (primary), 15 (high school)	**Grade:** 2nd grade, 9th grade

Teaching Approach	Competences of the curriculum units	Types of activities (brief description)	Evaluation (type & means of evaluation)
Due to the relatively small age the teachers use a variety of methods to gain students attention: Storytelling, explanation, demonstration of action, visualization, observation, comparison, discussion, association, working in groups and role games. Recommended is also the use of pictures, photos and posters as supporting tools <u>Example (earthquakes):</u> Position: Sofia Bulgaria, 1858 Tools: Stories, descriptions Theme: Disaster protection Theories: Safe behavior Terms: Vibrations, earthquakes, earth layers, destructive actions, relief, evacuation, disaster Skills: to identify, to describe, to count, to follow the rules, to work in teams	**2nd grade** **Concept competences:** Students acquire knowledge about the nature and characteristics of the earthquake as an unexpected disaster with great speed and varying destructive power - sounds flutter to the ground, movement of the earth's crust; the students acquire knowledge about the dangers caused by the earthquake disaster; Students acquire rules of safe behavior before, during and after an earthquake; consolidation of knowledge about precautions to reduce the risk of injury and infection; practical utilization of the Action Plan in an earthquake, acquainted with how to leave safely and immediately from the building after the first quake. **Skills competences:** Various, depending on the role games and simulations <u>Skill competence example:</u> Recognizes the earthquakes by their characteristics (sounds	**2nd grade** How can the lesson be conducted? (Information for the teacher) Knowledge could be enriched through a "brainstorming" - to the question "What do you imagine when you hear the word "disaster?" Count the characteristics that define a natural phenomenon as a disaster. The introduction of the topic is carried out by the teacher after reading a popular science text. The discussion is set by the teacher with the question: "Which natural phenomenon is described in the text?" During the discussion the teacher can clarify what is the center of an earthquake (epicenter) and the Science that deals with these issues (seismology). The discussion continues by focusing on the list of characteristics that classifies the earthquake as a disaster. The topic of discussion is directed to the occurrence of earthquakes both on land and in seas and oceans. Students' attention is drawn to the fact that this natural phenomenon cannot be predicted and prevented. Its duration is	The success indicators of the Environment curriculum provide the context of evaluation: →Formative assessment of the achievement of the lesson/s competences (skills, concepts) and teaching during the learning procedure – students explain what they understand about earthquakes, their reaction and proper behavior, need for preliminary planning for quick evacuation from home or school, survival kits etc. →Diagnostic and final evaluation happens progressively according to specific criteria – teachers set specific questions to the students for different phases of the earthquake, proper conduct in each phase, behavior after earthquake situation, potential risks after earthquakes etc. <u>Examples of means of evaluation:</u> -observation - comparison - role game situation -self assessment - teamwork and critical thinking encouragement

	that accompany the flutter and movement of the earth's crust, time for destructive actions - 10 sec.); describes possible damage due to the earthquake, which characterize it as a natural disaster; comply with the instructions of the teachers, guidance on radio, television; directed to the safest places in the building (school, home) and safest route for them; prepare basic necessities and valuables for leaving the building; observe personal hygiene because of the danger of epidemics; comply with the guidelines for orderly leave from the classroom and the school immediately after the first earthquake at a particular location; assist in checking that the students are brought out; knows the main activities and instructions stipulated in the Action Plan in an earthquake	not long, but the consequences are severe. To avoid casualties and heavy material damage the state authorities need to take action. Particular attention is paid to the fact that the proper communication can be life-saving. With group work named: "What should we do in an earthquake situation?" engage the attention of all students and provoke their activity. Each group must submit its task solution in an attractive way: short show, album of paintings, poster paper. At the discretion of the teacher, analysis of the work of the groups and the improvement of their knowledge can be accomplished in two ways: Read the rules proposed by the responsible state institutions and compare them with the solutions proposed by the groups. Students work with photos, make verbal description of the possible damages caused by the earthquake and use some of the previously proposed by the teacher's words to compile an oral story. At the discretion of the teacher the term "evacuation" is clarified and rules for safe removal of students from school are recalled.	

Teachers must clarify the causes of various natural hazards (earthquakes, floods, landslides, etc.) and their consequences. <u>Examples of teaching practices:</u> -exploratory learning -problem-solving learning - discussion - teamwork and mutual assistance - situation games Supporting materials – presentations, training videos, schemes and diagrams	**9th grade** **Concept competences:** 1. Identify the different kinds of natural hazards and their causes 2. Tracks map areas with territorial manifestation of spontaneous natural phenomena 3. Awareness of man's dependence upon natural spontaneous phenomenon and the need to combat them	**9th grade** Throughout the course of study the class must go through the following: 1. Define the term "natural hazard" 2. Classify natural risks, depending on the causes of their origin. 3. Made a paper for major natural disasters and their consequences 4. Know the rules of conduct during natural disaster situations 5. Comment the possible forecasting and combat with elemental natural phenomena	The success indicators of the national geography curriculum provide the context of evaluation: →Formative assessment of the achievement of the lesson/s competences (skills, concepts) during the learning procedure: Understanding key new concepts such as: • Natural risk • Classification of natural hazards • Monitoring Raising awareness about existing opportunities for cross-curricular links: physics: electromagnetic waves; epicenter etc. →Diagnostic and final evaluation happens progressively according to specific criteria <u>Examples of means of evaluation:</u> -observation -brain attack - understanding of thematic maps - active attitude to the problem - self assessment

Mapping the earthquakes with the national curriculum of Cyprus

Domain:	Geography		
Sub – domain:	Geology		
School level: Primary, Middle school	**Age:** 11 – 14	**Grade:** 6th – 8th grade	
Teaching Approach	**Competences of the curriculum units**	**Types of activities (brief description)**	**Evaluation (type & means of evaluation)**
Investigations with the use of tools (e.g. maps, photographs, charts, computer simulations) that are taught to students, used and/or made by students. The lessons are structured based on titles that derived from different sections (position, tools, theme, theories, terms, skills). Teachers must take into consideration the success indicators of the national geography curriculum. Skills are the guide for the organization of the activities. <u>Example (earthquakes):</u> Position: East Asia Tools: Small scale maps, photographs, videos Theme: Geology Theories: Tectonic processes Terms: Tectonic plates, earthquakes Skills: Influence zone, relationships, district	**6th grade** **Concept competences:** -Explain that the Earth's crust consists of a number of tectonic plates -Conclude from maps that the boundaries of tectonic plates are associated with seismic zones **Skills competences:** Numerous skills are mentioned in the curriculum. Teachers choose skills, attitudes and behaviors they want to develop. <u>Skill competence example:</u> -Handle digital globe and maps	**6th grade** Due to the reformation of the national curriculum, new books were developed, for now only for the first four grades of primary school. Therefore, there is no correlation between the curriculum competences and the activities that are embedded in the 6th grade book. Earthquakes are only briefly mentioned in a chapter about Japan without the direct involvement with the subject.	The success indicators of the national geography curriculum provide the context of evaluation →Formative assessment of the achievement of the lesson/s competences (skills, concepts) and teaching during the learning procedure →Diagnostic and final evaluation happens progressively according to specific criteria <u>Examples of means of evaluation:</u> -observation -creation/comparison/ understanding of thematic maps -portfolio -self assessment -diagnostic tests

Teachers must take into consideration the success indicators of the national geography curriculum. Skills (Geo–literacy, epistemological adequacy) are the guide for choosing a teaching approach and practices that define classroom organization, tools and teacher and students role. <u>Examples of teaching practices:</u> -exploratory learning -problem-solving learning -collaborative learning (constructivism) - Investigations -field Research	**7th grade** **Concept competences:** -distinguish a natural hazard from a natural disaster -recognize and name natural hazards and disasters that threaten and affect the planet -mention and describe ways to deal with emergency situations in personal, local and national level -criticize the power of media to choose and present natural disasters	**7th grade** Small thematic chapters that refer to: -what is natural danger and natural disaster (e.g. .earthquakes, tsunamis, interaction between disasters) -meet EMAK (Special response unit for disasters) With gap filling exercises and questions after each chapter	The success indicators of the national geography curriculum provide the context of evaluation →Formative assessment of the achievement of the lesson/s competences (skills, concepts) and teaching during the learning procedure. →Diagnostic and final evaluation happens progressively according to specific criteria <u>Examples of means of evaluation:</u> -observation -creation/comparison/ understanding of thematic maps -portfolio -self assessment -diagnostic tests
	8th grade No specific concept competences were written for the 8th grade because Cyprus geography is no longer part of the school curriculum due to a reduction in the teaching hours of the subject.	**8th grade** Small thematic chapters that refer to: -structure of earth -description of tectonic plates movements -creation of Cyprus -types of stones With gap filling exercises and closed questions after each chapter	

Mapping the earthquakes with the national curriculum of Greece

Domain:	Geography (for Primary and Middle schools), Physics (for High school)
Sub – domain:	Geology (for Primary and Middle schools), Physics(Motion and Velocity, Waves)

School level: Primary school, Middle school, High school	**Age:** 6 – 12 (Primary), 12 – 15 (Middle), 15 – 18 (High)	**Grades (that SSE project may be applied):** 6th grade, 1st and 2nd grade, 1st grade

Teaching Approach	**Competences of the curriculum units**	**Types of activities (brief description)**	**Evaluation (type & means of evaluation)**
Investigations with the use of multimedia and tools including maps, satellite photographs, computer simulations and animations that are demonstrated and taught to students, used and manipulated or made by students. Traditional lessons of expository instruction by teachers may be complemented by hands-on activities for students within the school classroom and regular time-schedule or out-of-school activities such as a field trip or visit to a natural history or geology museum <u>Example (earthquakes):</u> Position: Mediterranean area Tools: scale maps in paper or electronic format displayed by projector ,other multimedia resources like photographs, videos Theme: Geology and Geography Theories: Tectonic processes Terms: Tectonic plates, earthquakes, seismicity, volcanic activity	**Primary school, 6th grade** **Middle school, 1st and 2nd grade** **Concept competences:** -Explain that the Earth's crust consists of a number of tectonic plates -Explain what is an earthquake -Conclude from maps that the boundaries of tectonic plates are associated with seismic zones -Natural phenomena and impact **Skills competences:** -Handle scale maps and globe -distinguish a natural hazard from a natural disaster -recognize and name natural hazards and disasters that threaten and affect the planet -explain what their impact to society, to ecosystems etc. is -mention and describe ways to deal with emergency situations in individual, local and national level	<u>Example of related activities:</u> -students make thematic projects -school or classroom visit to a natural history or geology museum -identification of different types of stones and their origin -creation of our country's landscape, mountains, islands etc. -earthquake awareness day, what do we do in case of an earthquake, -video or documentary movie presentation discussion and reflection	The national science/geography curriculum describes the general framework of student assessment and evaluation of the learning procedure. It includes: formative assessment, diagnostic evaluation and monitoring, and final evaluation <u>Examples of means of evaluation:</u> -questioning and observation -creation/comparison/ understanding of thematic maps -diagnostic tests -interim and final exams, summative assessment

Teachers take into consideration the learning success indicators of the national geography curriculum. Students skills developed include geo–literacy, geo-spatial thinking, awareness of natural phenomena and their impact. Teachers choose teaching approach and practices for classroom organization, activities, tools and students' role taking into account available curriculum flexibility with respect to time and resources <u>Examples of teaching practices:</u> -exploratory learning -investigations and field research -collaborative and inquiry learning	**High school, 1st grade** At high-school level Geology and Geography subjects are not in the science curriculum. However the study of the theme of earthquakes gives a lot of opportunities for interdisciplinary teaching and learning within the subjects of Physics and Mathematics/ Geometry/ Statistics. In particular earthquakes, their creation and propagation, can be related to the concepts of Motion and Velocity, Waves and their Propagation, Triangulation etc. Within this context **Concept competences:** -What is an earthquake and how do we measure its parameters -What is seismic wave -Natural phenomena, natural disasters and impact. How to protect from, how to react to **Skills competences:** -Handle and understand scientific data -operation of a scientific instrument -collection and analysis of data, scientific inquiry, make hypothesis, do investigation and research, conclude from evidence -increased awareness about natural disasters, threats and risks and impact -(in case of assignment of project work to groups of students) skills of collaboration, communication,	<u>Example of related activities:</u> -students make thematic projects related to earthquakes. -students collect and analyze earthquake data from online repositories or seismometers -students make a video or presentation related to recent earthquakes in the country or around the world and their impact to society and the environment (e.g. destruction of the Fukushima nuclear reactor, impact of tsunamis etc)	

	presentation		

Mapping the earthquakes with the national curriculum of Italy

Domain:	Science, physics		
Sub – domain:	Earth science		
School level: High school	**Age:** 14 - 18	**Grade:** 9th - 13th grade Related topics in more depth: 12th & 13th grade	

Teaching Approach	Competences of the curriculum units	Types of activities (brief description)	Evaluation (type & means of evaluation)
The study of seismology is taken on more or less in depth depending on the curricular background of the teacher. In general is less significant than chemistry or biology as well as laboratory experimental activities. Several Italian teachers in science attend training and teaching experiences about non formal education of seismology in the framework of related educational projects and in this case maybe their students are involved in experimental experiences.	**Concept competences:** - Earthquake definition -Where and why earthquakes occur (earthquakes distribution on Earth's surface, relationships between earthquakes and tectonic plates etc.) -How earthquakes are generated (focal mechanism, mechanical behavior of rocks, kinds of faults, typologies of seismic waves and their propagation). -How to record an earthquake: devices and data. -Seismographs, mean and interpretation (pattern and duration depending on distance and magnitude etc.) -Measure of earthquakes (intensity MCS, magnitude and momentum magnitude) -Seismic risk with a particular focus on Italian territory, earthquakes forecast and prediction -Direct effects of earthquakes (ground shaking and buildings fall), indirect effects (tsunamis, landslides, liquefaction of sands, etc.).	-Frontal lesson and consequential study on textbooks. -Some laboratorial experiences can be applied if the teacher is particularly interested to seismology (because of background, interest or training project attendance). In this case students can be involved in such activities like the ones envisaging the use of ICT exploiting resources and data available online or even the assembly of technical devices such as educational seismographs. However these cases can be still considered as exceptions.	According to the program indications in science by the Italian Ministry of Education, students should attend periodical evaluation tests. The main Italian school publishers provide teachers with thematic test models in curricular subjects

	Skills Competences: -To know what an earthquakes is and contextualize this phenomena in the wider framework of Earth's crust dynamics -To know the means of such Earthquakes related definitions as different kinds of fault, different ground motions, direct and indirect effects of an earthquakes, etc. -To know the main tools and devices aimed to get seismic data and their working, and be able to interpret, at least in a descriptive way, these data -To be aware of seismic risk, with a particular focus on the risk in the territory where they live, and of a correct behavior in case of earthquakes		

Mapping the earthquakes with the national curriculum of Turkey

Domain:	Science				
Sub – domain:	Physical Events				
School level:	Secondary school	**Age:**	13 - 14	**Grade:**	grade 8

Teaching Approach	Competences of the curriculum units	Types of activities (brief description)	Evaluation (type & means of evaluation)
The planning and application of lessons are based on learning environments in which the students are active and the teachers are facilitators. For meaningful and permanent learning of the information in the field of science, in-class and out of school learning environments are designed according to inquiry-based learning strategy for students. In this regard informal learning environments like science, art and archeology museums, zoos, natural environments are also used. The process of research and questioning is not only regarded as exploration and experiment but also the as process of explaining and creating arguments. In short, the students create the information in their own minds by practicing-experiencing-thinking like scientists. Teachers allow their students to take part in dialogues through which they can articulate their ideas, support their thoughts with different justifications, and develop opposite dissertations to refute their friends' theses. In discussions,	**Competences:** -define general concepts on seismology such as seismologist, aftershock, foreshock, intensity of earthquake, fault line, fault line break, earthquake zone; -describe that seismology is a science field and the scientist working in this field is called seismologist; -make a connection between Turkey's earthquake zones and fault lines; -argue about reasons of earthquake and emergent adverse outcomes; -state that not only fault lines but also volcanic eruptions cause earthquakes; -discuss precautions against the risk of earthquake, and things to be done during an earthquake.	<u>Example of related activities:</u> -Reading the news on the newspapers and internet about the big earthquakes in Turkey in the classroom. -Watching a movie of how earthquakes happen - Using play dough to demonstrate plate movements -Students are given an investigation to search what can be done before, during and after earthquakes and then explain these precautions in the classroom.	In the science curriculum, an assessment approach which serves for the intention of monitoring and directing students in the process, identifying learning difficulties and elimination of them, supporting meaningful and permanent learning by providing continuous feedback has been adopted. Having a meaning of the numerical values obtained in the result, the monitoring of student progress and the direction of the student according to this progress are among the important principles of the curriculum. The point of view based on assessment depends on the assessment understanding of evaluating the process as well as product; so it is suggested that together with the learning outcome, the performance of the student should be assessed at the end of the process. It is also suggested that complementary assessment tools and techniques should be used since the numerical values

students present their claims with justifications which they create through valid data. Teachers take the role of guiding directors in these written or verbal discussions that have opposite theses.			obtained through traditional assessment tools do not have a meaning alone. By the use of complementary assessment tools and techniques process oriented assessment approach is emphasized. Self-assessment and peer assessment approaches by which the student has the chance of evaluating himself and his friend are adopted. Also, technology is used in order to monitor and assess the learning process of students and their performance at the end of this process.

The activities and educational approaches, that are briefly descripted in the Tables above, provide a space of freedom to teachers to choose how and when to integrate their selected activities into their teaching practice and the types of evaluation and teaching methods to follow. However, while the curriculum suggests contemporary teaching methods, the teaching materials and the associated activities are mostly text –driven and can be considered as “traditional” (see Cyprus and Italy national curriculum in abovementioned tables for example). Hence, when the teachers are not well informed and trained to implement IBL in their science classrooms, they tend to prefer these traditional approaches, especially for a concept like earthquakes. This particular situation is also aggravated because of teachers’ lack of background knowledge and understanding of the means used, such as seismographs and databases. Therefore, the SSE project and its Intellectual Outputs can provide the basic information that a teacher will need in order to design and implement a successful inquiry based lesson.

By reviewing the information that was provided by representative organizations from each country, the significance and importance of the current project’s contribution towards approaching the study of earthquakes from an inquiry-oriented perspective is prevalent. The SSE project provides the opportunity to educational systems and schools of the participating countries to integrate and study earthquake concepts within the context of their science curriculum. In addition, the SSE project aims to facilitate cooperation and relations between their schools and communities. The teachers can then use this network to enhance science lessons (with materials, equipment and other means), motivate students, renew educational methods and improve the quality of teaching.

8.2. The educational and pedagogical role of the teachers leading the students involved

Any science education teacher has a flexible and guiding role in the process of inquiry by providing a suitable learning environment that focuses on the learning process rather than the knowledge acquisition (Marks, 2013). Inquiry sometimes might be challenging for students. By providing a variety of stimuli and activities that meet students' pre-existing knowledge and learning style, a teacher creates learning experiences that are needed in order to understand how the world functions (NSF, 2000). The learning process is centered on the participation in basic inquiry tasks such as formulating questions, identifying variables, conducting experiments and drawing conclusions.

A teacher must possess skills and certain attitudes in order to encourage and support IBL (Colburn, 2000; Maaß & Doorman, 2013) in his/her own practice. The NRC (2000) refers to six standards that focus on inquiry classrooms. Inquiry is strongly aligned with these standards. They refer to practices a teacher should adopt and implement in order to ensure that students are involved in effective science activities, which interest them and provide them with the best opportunities for developing knowledge and skills.

A science teacher:

a) Plans an inquiry-based science program for their students
b) Guides and facilitates learning
c) Engages in ongoing assessment of teaching and of student learning
d) Designs and manages learning environments that provide students with the time, space, and resources needed for learning science
e) Develops communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning
f) Actively participates in the ongoing planning and development of the school science program.

(NRC, 2000, pp. 22 - 23)

Within the context of the SSE project, teachers must not only be able to aid students during the process of gaining skills and knowledge but also, because of the nature of the concept, to promote citizenship and civil responsibility. Earthquakes constitute a real world problem that connects with public awareness and civil protection. Therefore students must consider the societal impact of earthquakes while getting involved with activities that promote the improvement of problem solving skills and collaboration.

8.3. Further sound concepts and tools for the development of additional inquiry based learning scenarios

Approaching the study of earthquakes through an inquiry-driven approach requires quite often the construction of models or the use of ready-made models and/or simulations. This stance departs from the notion that the phenomenon of an earthquake occurs in a limited amount of time and thus inferences about the characteristics of the earthquake (e.g., earthquake's magnitude, nature, etc) can be drawn through the study of data collected with the use of specially designed devices such as seismographs. By analyzing the collected data, individuals seek to understand the mechanism through which the earthquake occurred and in doing so, they create models as means to represent and explain the phenomenon and at a later stage use them for formulating and testing of predictions for possible future earthquakes. This process reflects the process of modeling that is followed in order to improve our understandings about aspects of certain physical phenomena.

Consequently, modeling represents an authentic *scientific enterprise*, since scientists develop models in order to build and elaborate their own understanding about their research domains. In addition, modeling could be viewed as an instructional approach, when used as a platform to help students develop understanding of the content, the process, and the epistemology of science through building, testing, refining, and validating models of observed phenomena or complex systems.

Model building is in line with constructionist theories of learning (Papert, 1991); in order to build an internal, mental model of a particular scientific phenomenon, learners need to construct external representations or artifacts of the phenomenon under study, and as Jackson (1995) put it, “to develop that level of understanding, students need to engage in the activities of modeling, e.g., questioning, predicting, constructing, verifying” (p. 7). Modeling activities provide opportunities for teachers’ to better monitor students’ progression from their initial and probably naive understanding of a phenomenon or a concept under study to a more comprehensive and epistemologically acceptable conception of these phenomena and concepts. Additionally, engaging students in the iterative and cyclical processes of model development and deployment would enable them to: (i) express and externalize their own internalized mental models and thus to express their own thinking; (iii) examine abstract scientific phenomena in a way that meets their cognitive ability; (iv) solve problems; (v) coordinate and integrate facts with scientific theory rather than passively collect facts and formulas, etc.

Following Rogat’s et al. (2006) recommendations of how learners can be engaged in meaningful modeling processes, the following modeling practices can be integrated within the context of the SSE project:

a) **Construct (develop models):** Learners use data collected through a seismograph to construct a model of an earthquake. In their model, they might seek to represent the phenomenon under study and provide a mechanism that explains how the phenomenon functions.
b) **Use (explain, test, and predict through the use of a model):** Learners use ready-made models to explain how an earthquake occurred (e.g. identification of the mechanism that controlled the behavior of a certain earthquake), or use a model to formulate and test of predictions for future earthquake activity.
c) **Evaluate (identify limitations, determine explanatory power):** Learners evaluate their own evolved models or ready-made ones on the basis of certain criteria, e.g., model’s *representational complexity* (e.g., does the model represent the phenomenon under

study?), *explanatory potential* (e.g., does the model provide a possible mechanism that helps in explaining how and why the phenomenon functioned the way it did?) and *predictive power* (e.g., does the model allow the formulation and testing of predictions for phenomenon's future behavior?).

d) **Revise (revise a model to strengthen its explanatory power):** Learners revise their own models or ready-made models after comparisons made with the physical phenomenon they relate to and on the basis of certain criteria such as model's representational complexity, explanatory potential, and predictive power.

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