When the Past Teaches the Future: Earthquake and Tsunami Risk Reduction Through Episodes of Situated Learning (ESL)

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Article

When the Past Teaches the Future: Earthquake and Tsunami Risk Reduction Through Episodes of Situated Learning (*ESL)*

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Abstract: The past is an important lesson for facing the future with greater awareness. In this context, school plays a key role to spread knowledge on natural phenomena and to promote behavior change. Together with researchers, teachers can be strong allies to build more resilient future citizens. The Istituto Nazionale di Geofisica e Vulcanologia (INGV) school training activities provide tools to get ready for the next earthquake and/or tsunamis. About 5000 students from both Middle schools (ISCED 2) and High schools (ISCED 3) were involved in *active learning* activities based on a flipped-up approach during special online scientific events in the Pandemic. Online lab activities were conducted respectively during the European Researchers' Night ("*Earthquakes: history teaches us the future: researchers for a day with experimentation in didactics for ESL"*) and during the World Water Day 2021 and the World Earth Day 2021 ("*Tsunamis: history teaches us the future researchers for a day with experimentation in didactics for ESL"*). These two *Episodes of Situated Learning (ELS)* experiences triggered students' interest, favoring remote learning, developing life skills, focusing on historical seismic studies of both past earthquakes and tsunamis.

Keywords: *Episodes of Situated Learning (ESL)*; *active learning*; *critical thinking*; prevention; natural risk preparedness; damage; earthquake; tsunami; seismic risk reduction; education

1. Introduction

As Thucydides taught, as early as the 5th century B.C., "One must know the past in order to understand the present and affect the future". More recently, Carl Sagan once famously put it "You have to know the past to understand the present". The past and the future are actually not so different, and this concept is even truer when it concerns natural hazards. Indeed, if an area has been affected in the past by significant natural events (earthquakes, tsunamis, floods), similar events will certainly occur again in the future, because every natural past event has causes that work in the exact same way. Likewise, each past event has implications on the future ones and, when a disaster event takes place, society is deeply transformed. So, for a better understanding of the future we have to study looking to the past with a critical approach.

The designed educational activities described in this paper aim at triggering critical thinking, stimulating reflection and increasing preparedness for response to earthquakes and tsunamis and thus strengthening resilience [1].

According to the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters, International Strategy for Disaster Reduction and to the Chart of the Sendai Framework for Disaster Risk Reduction (2015-2030), particularly to Priority 1 (Understanding disaster risk), we aimed at the substantial reduction of disaster risk and losses in lives for a more resilient society (UNISDR, 2015; https://www.preventionweb.net/files/44983_sendaiframeworkchart.pdf). The INGV activity

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addressed to schools is focused on the prevention of future natural events, favoring the reduction of hazard exposure and vulnerability to disaster.

Since the introduction of the *Situated Learning Episodes (ESL)* method in Italy by Prof. Rivoltella [2,3], INGV has applied it to its research topics in order to involve students by using technology at school [4].

Following the *ESL* methodology, complex scientific concepts are "divided" into small fundamental knowledge that students can acquire in order to transfer key concepts to their peers. Students' communication products, i.e. digital posters, are the creative results of their personal learning process. *ESL* is structured in 3 phases: preparatory, operative and debriefing, performing the principles of *flipped lesson* [5]. The researchers were not mere "dispensers of knowledge", but they were tutors in an assisted laboratory to come up with significant observations and considerations through shared research and reworking of *learning by doing* activity.

The need to design engaging and educational distance learning activities to support students and teachers during the COVID19 Pandemic has led to test the online use of this innovative digital teaching method, previously used only in presence [6,7].

On the occasion of the European Research Night 2020, and on both the World Water and Earth Days 2021, the distance lab activities "Earthquakes: history teaches us the future" and "Tsunamis: history teaches us the future" were thus performed by INGV. The first ESL was experimented within the NET Science Together project, and the second one was tested both within the European Interreg Italy-Croatia project called PMO-GATE, and within the project FCR (Future Responsible Citizens) - Educational Paths of Civil and Environmental Responsibility) in collaboration with the Italian Associazione per lo Sviluppo SOstenibile e Centro di Educazione Ambientale (ASSOCEA Messina APS).

About 2200 students of Middle Schools third classes and of all classes of High Schools took part in our *ESL* experimentation. After the INGV researchers' explanatory lesson on past earthquakes and tsunamis, students have become "researchers for a day" and prepared, independently, 150 creative digital artifacts on some of the most important historical events of their region. Researchers' knowledge was at the service of School using a curiosity-driven approach in order to help homebound teachers and students during the Pandemic. The activities aim to increase the awareness of the risks related to earthquakes and tsunamis through the study of past events, bringing students closer to the world of research and encouraging them to independently develop the contents discussed with the experts. The main purpose is to understand how the past is an important key to reduce the impact of future events. At the end of this experiment, some students have reported their experience on *"Noi Magazine"*, the insert of *Gazzetta del Sud* dedicated to education.

At the end of each scientific special event, differentiated satisfaction questionnaires were distributed to both teachers and students. The feedback was very useful in assessing the perception and appreciation of our educational learning activities and they encouraged us in the design of new *ESL*s. In addition, every teacher, every student and all classes were handed with a certificate of participation to the event.

2. Materials and Methods

2.1. Episodes of Situated Learning (ESL)

This paper intends to present a new didactic model experienced and based on the *ESL (Situated Learning Episode)* method. *ESL* works on the minimum didactic unit that is the barycenter from which the teacher's didactic action is developed. The structure of an *ESL* consists in a natural ternary of the school setting management [8]. Each phase can be considered a stage of the learning process and it corresponds to a teaching logic, as schematized in Figure 1:

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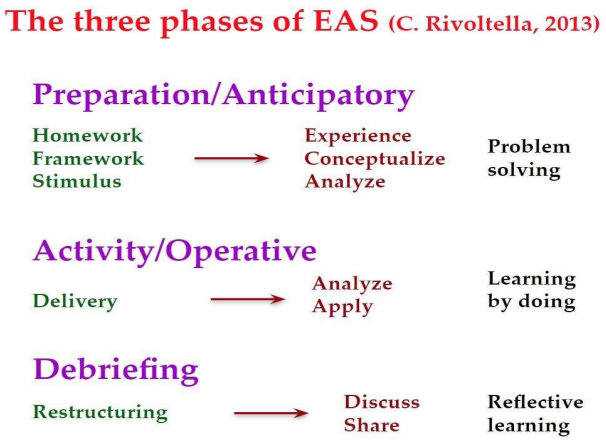

Figure 1. ESL methodological framework.

The three fundamental steps are always presented in sequence, but they are in a relationship with each other: 1. The ***anticipatory moment***, which consists of a *stimulus-situation* (conceptual framework, video, image, experience, document, testimony); 2. The ***operative moment***, which consists of a *micro-production activity* (analysis/creation of a text starting from a problem to be solved); 3. The ***debriefing moment***, which consists of the restructuring of what has been realized in the previous two steps [9].

Actually, students design a communication product in a context that challenges knowledge, skills, attitudes and competences; on the other hand, teachers enforce learning and, thanks to this method, can evaluate all the three phases of *ESL* activity to reach a formative assessment. In fact, the students' evaluation is at the same time evolutionary (it verifies the development of competences), comprehensive of the *in itinere* evaluation moments, and coherent with the actions carried out [10,11].

The *ESL* method has its genesis with *mobile learning* and it has been widespread since the introduction of tablets in schools, but it should be considered as an integrated approach to teaching. This model entails a radical redefinition of all three macro-actions in which teaching is divided: 1. *Planning*, which is rethought in modular terms [12]; 2. *Communication*: overcomes the concept of "frontal lessons vs active didactics", focusing on problem solving, making and sharing the new digital products, ending with a collective reflection; 3. *Assessment*, evolving towards the concept of New Assessment, with particular attention to embedded tasks and cumulative tasks [13].

Designing *ESL* requires some fundamentals: selecting the *microcontents*, providing scaffolding, determining and supporting the role of the teacher and assessing situated learning. This implies the need for careful design work [14] rather than planning, with a perspective that could be defined as "assembling cultural objects" [15,16].

Didactics for *ESL* consists of finding simple solutions to complex phenomena, as exemplified by problem solving in a complex situated context. Applying a *"simplex"* strategy means striving for very advanced solutions, reducing the effort required to manage them. The *"Simplexity"* neologism stands for a possible complementary relationship between complexity and simplicity, looking for simplicity through design [17,18]. Thanks to Berthoz's theory on *simplexity*, the *ESL* method turns out to be a significant learning experience with a strong cognitive transferability. Classrooms using the *ESL* method apply the "enactivist" concept, that is the dynamic interaction of students with their environment [19].

The *ESL* has a flipped up teaching approach (at home students get information, at school they learn), which is quite different from a traditional lesson (at school students catch concepts, at home they study). Homework is for learning and acquiring new skills, while classwork is for reworking and understanding [20].

In the *ESL* method the *flipped classroom* is integrated with *cooperative learning*, making it possible to reach the highest levels of Bloom's taxonomy, that is structured in this way, starting from the basis of the Bloom's pyramid:

- **remember**: recall facts and basic concepts, which means define, duplicate, list, memorize, repeat and state; **understanding**: explain ideas or concepts, which means classify, describe, discuss, explain, locate, recognize, report, select and translate;
- **apply:** use information in new situations, which means execute, implement, solve, use, demonstrate, interpret, operate, schedule, sketch;
- **analyze**: draw connections among ideas, which means differentiate, organize, relate, compare, contrast, distinguish, examine, experiment, question and test;
- **evaluate**: justify a stand decision, which means appraise, argue, defend, judge, select, support, value, critique and weigh;
- **create**: produce new or original work, which means design, assemble, construct, conjecture, develop, formulate and investigate [21].

According to the European Commission Recommendation 2006/962/CE about the *Key Competences for Lifelong Learning*, *ESL* is a methodologic proposal for a "smart school" which trains students to be able to pool different experiences in order to optimize the use of their available resources and to develop problem-solving skills [22]. The development of *critical thinking* is favored by the reflection and the analysis of ideas that are necessary to carry out the assignment. Good critical thinkers are able to split a broad idea into many parts: they can examine each part, question biases, and come to a reasonable conclusion [23].

2.2. Experiments in innovative Geosciences Education through ESL as interactive teaching tools for modern School

Applying *ESL* methodology to Geosciences is an innovative system to involve both students and teachers in a new approach to teaching and learning, using simple digital tools to learn even complex concepts. This method was also proven to be very successful in activities addressed to School, aimed at reducing natural hazards and in teaching good practices for Civil Protection purposes. Our first *ESL* experiment produced comics on safe behavior in case of natural events [24]. Then, in the frame of the *KnowRisk (Know your city, Reduce seISmic risKthrough non-structural elements)* project, the *ESL* final digital outputs were creative products addressed to non-structural seismic risk reduction [25, 26, 27, 28]. Another *ESL*, titled *"A nuoto tra i vulcani Italiani" ("Swimming among the Italian volcanoes")*, developed for schools to spread the *ESL* method among teachers, was then designed to explain Italian seamounts using interactive maps. This latter *ESL* was also functional to be used on the occasion of the *European Researchers' Night 2019,* held in presence in Pisa in the framework of the *Bright* project.

On the basis of our previous experience, during the Pandemic we have created some *ESL* whose final products were interactive maps that were suitable to be discussed online during the debriefing phase in *distance learning*. Moreover, since topics related to macroseismic studies had to be dealt with, producing interactive maps as a digital output was the most suitable tool to approach this kind of research.

In order to make students know how the past is fundamental to understand the present for a better future, not only in History but also in Geophysics, we have developed a learning activity that would make them work as a geophysicist does. We therefore used the study of past seismic and tsunamigenic events to engage students in a self-made exercise in which they had to get involved in the first person, working in groups, experimenting with new digital techniques and presenting their results to others as researchers do at scientific conferences [29,30 31].

2.2.1. "Earthquakes: history teaches us the future - researchers for a day with experimentation in didactics for ELS"

The first *ESL* designed during the Pandemic was *"Earthquakes: history teaches us the future"*, addressed to students of the third classes of Middle Schools (ISCDE2) and of all classes of High

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Schools (ISCDE3). In the frame of the *NET Science Together* project (a Marie-Curie project funded by the European Commission), the *ESL* activity was performed on the occasion of a special edition of the *European Researchers' Night 2020*, held exclusively online for schools, in the week 23-27 November during the COVID19 Pandemic.

The "*Earthquakes: history teaches us the future - researchers for a day with experimentation in didactics for ELS"* special event was structured into two live streamings. During the first one, occurred on November 23rd, INGV researchers explained students and teachers the method and conducted a short preparatory lesson on the key concepts of earthquakes: what they are, what seismic waves are, what is the distinction between microseismology and macroseismology, the difference between magnitude and intensity, and what are the tools and the safe behaviors to adopt for prevention and self-protection. The researchers also talked about the importance of knowing past earthquakes and they explained how scientists work to reconstruct their effects. This was a fundamental step because the students' task was to choose an historical earthquake of their interest and study it as if they were true researchers. The students were asked to create an effective communication product addressed to their peers. To steer students in their work, they were provided with video stimulus, a list of earthquakes to choose from, a link to the CPTI15 historical seismicity database [32] and the Mercalli macroseismic scale. These students, working in *cooperative learning*, were divided into different groups in each class. As final products, they had to prepare a digital interactive intensity map of the chosen earthquake with linked multimedia files. In addition, they had to provide the seismic history of the studied region, starting from the list of earthquakes supplied by the researchers and integrating it with the data extracted from the CFTI15 database (see Figure 2). In the following two days the INGV researchers supported the classes during their creative work phase.

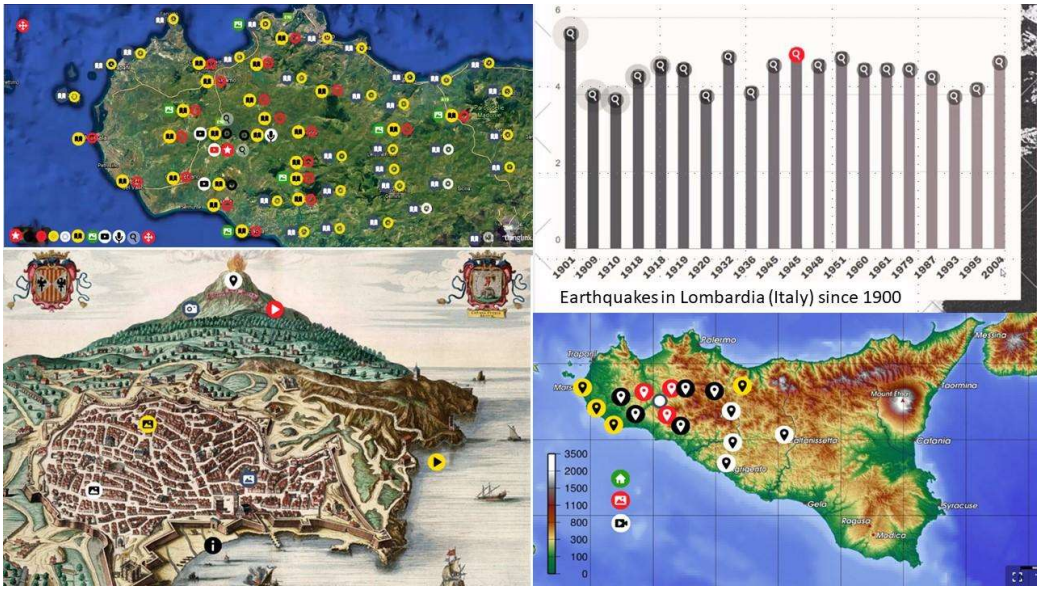

Figure 2. Some of the interactive maps designed by students involved in the "Earthquakes: history teaches us the future - researchers for a day with experimentation in didactics for ESL" educational online special event.

This event was attended by a total of 464 students and 18 teachers from 23 classrooms from all over Italy. In particular, 204 students were from 10 classes of the Middle Schools, producing 20 macroseismic interactive digital maps, while from High School's 260 students from 13 classes produced 38 interactives digital macroseismic maps. The researchers corrected in one day the 58 interactive products, realized by using the *Thinglink* free App (see Table 1).

Table 1. Schools involved in the "Earthquakes: history teaches us the future - researchers for a day with experimentation in didactics for ESL" educational online experience.

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Region	Middle Schools (ISCDE 2)	MS classes	MS Students	High Schools (ISCDE4)	HS classes	HS students	Total n. students
Lazio	1	1	28	1	2	53	81
Lombardia	2	3	57	-	-	-	57
Sicilia	-	-	-	1	4	83	83
Toscana	-	-	-	1	3	62	62
Liguria	2	2	39	1	1	10	49
Marche	1	4	80	-	-	-	80
Umbria	-	-	-	1	3	52	52
						TOTAL	**464**

Each map is the result of the team work composed of 4-5 students in *distance learning*. During the second live streaming, held on November 27th, the leaders of each student team presented the products of their groups for a collective *debriefing* phase conducted by the researchers.

The "Earthquakes: history teaches us the future ELS is summarized in table 2.

Table 2. The "Earthquakes: history teaches us the future" ESL. .

Titolo *ESL*	***Earthquake: history teaches us the future***
Authors	Giovanna Lucia Piangiamore and Alessandra Maramai, Istituto Nazionale di Geofisica e Vulcanologia (INGV)
Target (classroom, students age...)	Third classes of Middle schools (ISCED 3) and High schools (ISCED 4) classes (first to fifth) dealing with the study of earthquakes
Skills that the *ESL* aims to develop in students	Control and adaptability/Complex Dimension/Transferability Ability to represent identified relationships Can use groups of information for a personal representation of the topic Can use digital tools to visualize the distribution of tsunami effects on the coast Can be able to produce information Can use technology in a goal-oriented way Can produce a creative cultural object (interactive map)

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What will the student be able to do at the end of this *ESL*?	The aim is to bring young people closer to the world of research, fostering personal acquisition of the topics discussed with the experts and enabling an understanding of how the past is an important key to reduce the impact of future earthquakes. Through this experience, the student will understand that macroseismic study is fundamental in seismology and that to reconstruct the seismic history of an area is a very complex work including the use and the interpretation of seismic catalogues and historical documents. The knowledge of the seismic and tsunamigenic history of a place is the result of meticulous and deep work that includes the analysis of catalogues and historical documents. The *ESL* will be performed at the end of the learning unit on seismic risk. Starting from basic geological-geophysical knowledge (notions on earthquakes, difference between magnitude and intensity, what the seismic hazard is, macroseismic maps) the students will learn that earthquakes are not predictable and the past can teach about the future.		
PHASES	**DESIGN**	***App***	**TIMES**
PREPARATORY	**Homework** A stimulus lesson on the study of historical earthquakes is proposed, aimed at understanding the methodology used by seismological researchers to reconstruct past seismic events and construct a macroseismic map. Students are provided with: a table of the main earthquakes in their territory from 1900 to the present day, the Catalogue of Strong Italian Earthquakes (CFTI15) (http://storing.ingv.it/cfti/cfti5/), the Mercalli macroseismic scale (attached) as a necessary tool for assigning intensities, a very short explanatory video on macroseismic surveys (https://youtu.be/HsDdzy_YOUA?list=PL9AYW9rU1MgBHjM4eis98JGXrO5gxVWYO). Students should to try derive useful information from (http://www.blueplanetheart.it/2020/06/ingv-mille-anni-sismicita-italiana-nel-catalogo-cpti-database-macrosismico-dbmi/ and http://protezionecivile.unionerenolavinosamoggia.bo.it/images/Piano_ProtCiv/Sezioni_Piano_PC/Sezione2/SR4.1_RG001_Terremoto.pdf, https://ingvterremoti.com/i-terremoti-in-italia/) **Framework** At school, the teacher describes the key concepts on earthquakes with a power-point presentation: - what earthquakes are and why we study the historical ones; - which are the strongest earthquakes in Italy; - difference between magnitude and intensity; - intensity assessment; - macroseismic map;	Youtube (to see the video-stimulus) Powerpoint (to present the *framework*) DROPBOX (to insert file) Notepad (for notes)	Time required for each student to do homework 5'

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	Students fix the notions. **Stimulus** The teacher provides a video-stimulus on the topic: https://ingvterremoti.com/2014/12/01/i-terremoti-nella-storia-memoria-condivisa-tradizioni-popolari-e-il-terremoto-del-16-novembre-1894-nella-calabria-meridionale/ The aim is to make students curious and enthusiastic about the historical seismology of our country, developing the awareness that the Italian territory has a high seismicity and that earthquakes recur cyclically.		
OPERATING PHASE	**Assignment** As in the attached example, display the earthquakes of your area in the timeline. Create with *ThingLink* an interactive intensity map (macroseismic map) of the chosen earthquake, with any geographical base. Consult the CFTI15 catalogue to obtain the information needed to construct the map. Enrich with additional information on the chosen earthquake (parts of original texts with damage descriptions, historical images, maps, etc.) your digital map (you can use the Internet to search for material). *(The final product will be realized by small groups of 4-5 students, in order to have at the end a collection of interactive maps representative of the Italian territory. They can underline the importance of macroseismic studies to be emphasized in the debriefing).*	*ThingLink* (for interactive maps) Word processor (for the graph) DROPBOX/ DRIVE (for the assignment)	50' 15' 5'

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	Each group of students put the final product into a folder in Dropbox/Drive so that the shared document allows for immediate discussion of the results.		
DEBRIEFING PHASE	**Assessment and Discussion** *The teacher* critically analyzes the output of the students, selecting a few intensity maps, asking the students to present them, explaining the reasons for their choices; the teacher corrects final products; makes suggestions and actively participates in the collective discussion, clarifying the appropriate conclusions and highlighting what is most important and dwelling on misconceptions about earthquakes. *The students* analyze the results and they reflect on their own final products and on those of their peers, making observations on the different products. Metacognitive thinking is being developed, resulting from discussion with others, about their final products and the way in which it was carried out. **Output** Corrected digital works can be shared and posted on the Dropbox/Drive folder.	Notepad (to write conclusions) DROPBOX/ DRIVE (to archive the final report)	30'

Each *ESL* must be supplemented by an *assessment rubric*, which is a summary of statements describing a competence, indicating the degree of achievement of the set objectives, and by a *declination of competences grid* to help teachers in evaluation of their student involved in the *ESL* activities. In our case, both the *assessment rubric* and the *declination of competences rubric* are the same for the *"Earthquakes: history teaches us the future" and for the "Tsunamis: history teaches us the future" ELS*s (see table 3 and 4).

Assessment rubric

Table 3. The "Earthquakes: history teaches us the future" and the "Tsunamis: history teaches us the future" assessment rubric.

SIZES	**LEVELS**			
	Partial	**Essential**	**Medium**	**Excellent**

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Interpreting the representation	Interprets representations only when guided, has difficulty in extrapolating information and in identifying its overall meaning; has difficulty in using different codes and/or switching from one language to another	Interprets representations in an essential manner, partially extrapolates information and identifies some significant aspects, manages to use different codes and/or switches from one language to another	Autonomously interprets representations, extrapolates the most important information by identifying the meaning and reworking it using different codes and/or switching from one language to another in an appropriate manner	Interprets with confidence representations, extrapolates the most important information by identifying hidden meanings and reworking it using different codes and/or fully switching from one language to another and in a personal manner
Acting in an organizational and emotional-relational autonomy	Cannot act autonomously depending on the situation, needs support to overcome difficulties	Can act semi-autonomously according to the situation and should be encouraged to make the right choices (has some insecurities)	Can act autonomously and correctly, adapting to different situations	Is able to act autonomously, appropriately and consciously with confidence, adapting to different situations without losing heart. He/she is an example for others and supports peers in difficulty
PRODUCE	Uses technology in a simple way and can only produce simple composition if guided	Uses technology in an adequate manner and produces less than satisfactory work	Makes appropriate use of technology and produces simple but correct work	Makes targeted use of technology and produces original and personal work

Declination of the competences grid

Table 4. The "Earthquakes: history teaches us the future" and the "Tsunamis: history teaches us the future" declination of the competence grid.

SKILLS *(among the 8 'key' competences)*	**SIZES** *(Qualifying aspects)*	**CRITERIA** *(What the student must be able to do)*	**MARKERS** *(Objective evidences)*
Scientific skills	KNOWING THE REPRESENTATION	Knows how to navigate between the various types of representation	Knows the various representations and their structural characteristics
COMMUNICATE	KNOWING THE NECESSARY PROCEDURES TO INTERPRET REPRESENTATION	Knows how to proceed in reading the representation	Knows the phases of reading and identifies the knowledge/skills required to do it

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	INTERPRETING THE REPRESENTATION	Can extrapolate information from the representation	Explains a representation by identifying its global and analytical meaning
Social and civic skills **ACT AUTONOMOUSLY AND RESPONSIBLY**	Organizational autonomy	Can manage time, space and materials	Knows and sets up the necessary tools for various school activities, carries out individual and/or group work in the required time according to purpose. Recognises and respects rules
	Emotional-relational autonomy	Knows how to respect others, collaborate, help, listen and participate in discussions	Follows the rules of the classroom (how to participate in collective phases, waiting for their turn, respecting the times and working methods of their classmates)
Digital skills	COLLECT	Knows how to find information	Identifies the most reliable sources
			Critically selects the necessary information
	ORGANIZE	Can link information	Uses technology in a targeted manner
	PRODUCE	Can produce informazioni	Uses technology in a targeted manner
			Produces a creative cultural object

A further area in which we experimented the "Earthquakes: history teaches us the future - researchers for a day with experimentation in didactics for ELS" was a Path for Transversal Skills and Orientation (PTSO) pathway in a Scientific Liceum in Pavia, in the frame of the "Taramelli's Year". The project involved 34 students, from the fourth and fifth classes, who were divided into 8 working groups, participating with great interest. Six 2-hour online meetings with the students were held by INGV researchers in collaboration with the University of Pavia. Similar to the others ESL, during the first meeting the method was explained and the key concepts of earthquakes were introduced. Each group chose one event to be studied and had to produce the digital macroseismic map of the selected earthquake. The other online meetings were used to check the state of the art of the activity and to clarify students' doubts. Meanwhile, since the Pandemic restrictions had been reduced, it was decided that each working group would present the results of their work to students of other classes of their school, during a ceremony held in presence in the Lyceum's auditorium in May 2022.

At the same time of the *PTSO* experience with the *ESL* method applied to macroseismic, another similar initiative was carried out in the frame of the *"Taramellian Year"* organized by the University of Pavia in collaboration with the INGV. In this activity the learners were teachers, attending a 10-hour training course titled *"Teaching for ESL - Earthquake: history teaches us"*. The course was developed in 4 meetings held online from April to May 2022 and a specific lecture on the *ESL* method was held by Prof. Rivoltella.

2.2.2. Tsunamis: history teaches us the future - researchers for a day with experimentation in didactics for ESL

The enthusiastic feedback received from both teachers and students participating at *"Earthquakes: history teaches us the future - researchers for a day with experimentation in didactics for ESL"* led us to design a similar *ESL* dealing with tsunamis: *"Tsunamis: history teaches us the future - researchers for a day with experimentation in didactics for ESL"*. This online learning activity was aimed at reconstructing past tsunamis in the framework of the *PMO-GATE* project, in which INGV is involved in the study of tsunamis and meteotsunamis for the prevention of natural hazards and in the framework of the *FCR* project, in which INGV is involved in *CON.I.RI. (CONvivere con I Rischi naturali, - Living with natural hazards)*. This latter collaboration led us to an interaction with the daily newspaper *La Gazzetta del Sud*, in particular with its supplement *Noi Magazine*, edited by High school

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students from Calabria and Sicily. That's the reason we decided to involve in this *ESL* experimentation only Middle and High schools from Sicily and Calabria.

On the basis of our experience in the *ESL* on historical earthquakes, we gave students more time to design their digital maps, taking the opportunity of two important dates: the World Water Day (22nd March) and the World Earth Day (22nd April). The first live streaming was held by the INGV researchers on the occasion of the World Water Day 2021, to explain the *ESL* method and to raise awareness on a natural phenomenon whose risk on the Italian coasts is very often underestimated. At the same time, during the lesson the fundamentals on tsunamis were introduced: what tsunamis are, why and how past tsunamis are studied, the tsunami intensity scale, the most relevant tsunamis in the Mediterranean Sea and, particularly, along the Italian coasts. In addition, it was also explained how to reconstruct the tsunamigenic history of a locality/area of interest.

The *ESL* activity was focussed on the tsunami following the 1908 Messina (Sicily, Italy) earthquake, the strongest ever occurred in Italy. For this event the students had to reconstruct the effects produced in the locations nearest to their school's territory.

"Tsunamis: history teaches us the future - researchers for a day with experimentation in didactics for ESL" was attended by a total of 1707 students and 43 teachers from 107 classrooms from Sicily and Calabria. In particular, about 900 students were from 60 classes of the Middle Schools, producing 75 macroseismic interactive digital maps, while from all classes of the High Schools about 800 students from 47 classes produced 90 interactive digital macroseismic maps (see Figure 3).

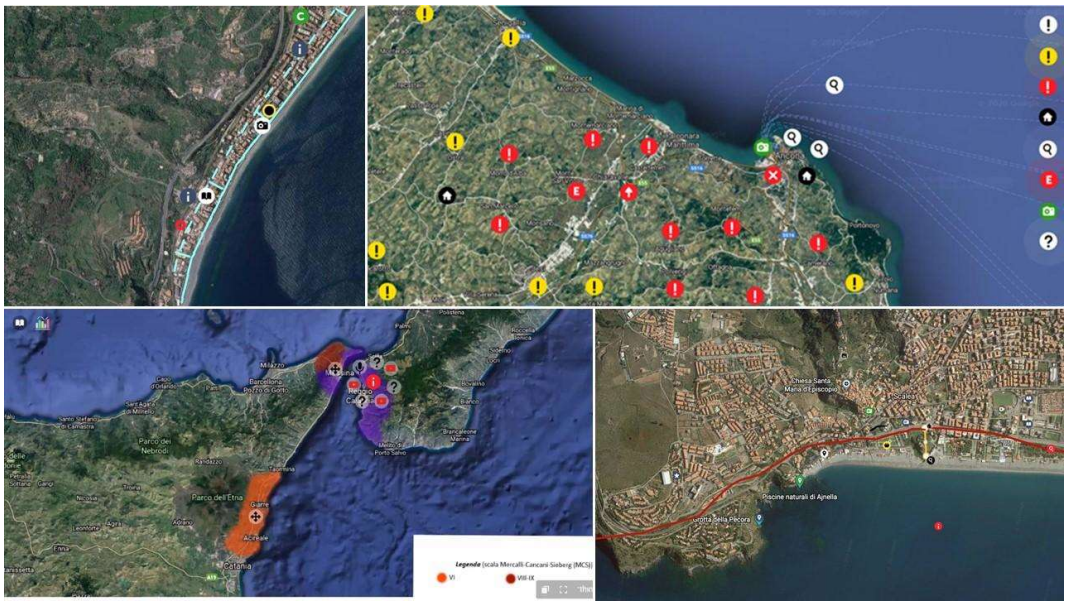

Figure 3. Some of the interactive maps designed by students involved in the "Tsunamis: history teaches us the future - researchers for a day with experimentation in didactics for ESL" educational online special event.

The researchers corrected in one week the 165 interactive maps, realized by using the *Thinglink* free App (see Table 5).

Table 5. Schools involved in the "Tsunamis: history teaches us the future - researchers for a day with experimentation in didactics for ESL" educational online special event. .

Province	Middle Schools ISCDE 2	MS classes	MS Students	High Schools ISCDE3	HS classes	HS students	Total n. students

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	1	3	55	-	-	-	55
Caltanissetta							
Catania	8	17	270	4	10	128	398
Cosenza	5	16	144				144
Siracusa	2	8	120	2	30	523	643
Trapani	1	3	54	-	-	-	54
Reggio Calabria	2	9	150	-	-	-	150
Messina	1	2	50				50
Enna	1	2	45				45
Crotone	-	-	-	1	2	39	39
Vibo Valentia	-	-	-	1	5	129	129
						TOTAL	**1707**

Also for this activity students were divided into working groups of 4-5, assisted remotely on demand by INGV researchers.

The "Tsunamis: history teaches us the future" ESL scheme is summarized in table 6.

Table 6. The "Tsunamis: history teaches us the future" ESL.

***ESL* Title**	***Tsunamis : history teaches us the future***
Authors	Giovanna Lucia Piangiamore and Alessandra Maramai, Istituto Nazionale di Geofisica e Vulcanologia (INGV)
Target (classroom, students age…)	Third classes of Middle schools (ISCED 3) and High schools (ISCED 4) classes (first to fifth) dealing with the study of tsunamis
Skills that the *ESL* aims to develop in students	Control and adaptability/Complex Dimension/Transferability Ability to represent identified relationships Can use groups of information for a personal representation of the topic Can use digital tools to visualize the distribution of tsunami effects on the coast Can be able to produce information Can use technology in a goal-oriented way Can produce a creative cultural object (interactive map)

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What will the student be able to do at the end of this EAS?	The aim is to bring young people closer to the world of research, fostering personal acquisition of the topics discussed with the experts and enabling an understanding of how the past is an important key to reduce the impact of future tsunamis. Through this experience, the student will understand that tsunamis are closely related to earthquakes and that, even for tsunamis, events that occurred in the past can be repeated in the future with similar characteristics. Reconstructing the effects of tsunamis is often difficult because the damage caused by the tsunami is added to that of the earthquake that generated the tsunami itself. The knowledge of the seismic and tsunamigenic history of a place is the result of meticulous and deep work that includes the analysis of catalogues and historical documents. In particular, the case study of the tsunami associated with the Messina earthquake of 1908 will be analyzed. The *ESL* will be performed at the end of the learning unit on seismic risk. Starting from basic geological-geophysical knowledge (notions of earthquake and tsunami, seismic and tsunami hazard maps, tsunami intensity assessment), the students will learn that even for tsunamis the past can teach about the future and that tsunami warning systems exist for risk reduction.

PHASES	**DESIGN**	***App***	**TIMES**
PREPARATORY PHASE	**Homework** A stimulus lesson on the study of historical tsunamis is proposed, aimed at understanding the phenomenon and how researchers reconstruct its effects. The activity will mainly focus on the reconstruction of the tsunami following the Messina earthquake of 1908. The database of the effects of Italian tsunamis is provided https://tsunamiarchive.ingv.it/en/tsunami-catalogues/ited-italian-tsunami-effects-database the Ambraseys-Sieberg scale as a tool for assigning tsunami intensity (attached). Students have to try to derive useful general information on tsunamis from the videos: https://www.ted.com/talks/alex_gendler_how_tsunamis_work/transcript?language=it#t-201827, https://www.youtube.com/watch?v=qTd62yuSOQM, on surveys of post-event effects https://vimeo.com/51246302 and from the INGV Tsunami Warning Centre website https://programming14-20.italy-croatia.eu/web/pmo-gate, https://www.ingv.it/ricerca/progetti-e-convenzioni/progetti/pmo-gate#abstract-2, https://cat.ingv.it/en/ **Framework** At school, the teacher describes the key concepts on tsunamis with a power-point presentation: - what tsunamis are and why we study the historical ones; - which are the strongest tsunamis in the world and in Italy; - the Messina tsunami of 1908;	Youtube (to see the video-stimolo) Power point (to present the *framework*) Notepad (for notes)	Time required for each student to do homework 5′

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	- tsunami intensity assessment; - map with distribution of tsunami effects. Students fix the notions. **Stimulus** The teacher provides a video stimulus on the 1908 Messina earthquake as an in-depth study https://www.youtube.com/watch?v=KkKAUY5IUVI (Quark) and https://www.youtube.com/watch?v=1pPGSylKLW8 (Mario Tozzi). The aim is to make students know that even in our country, tsunamis represent a real, often underestimated risk for coastlines.		
OPERATING PHASE	**Assignment** Create with ThingLink, with any geographical basis (Google Maps or similar is suggested), an interactive map representing the areas at greatest tsunami risk on the coasts of Sicily and Calabria, starting from the data of the 1908 Messina tsunami. You should identify and highlight the "strategic infrastructures" (schools, hospitals, police stations, etc.) present in the study area today. You have to consult the EMTC2.0/ITED online database to get the information needed to realize the map. Enrich your digital work with additional information on the tsunami for the different locations (description of effects, historical images, videos, etc.). You can use the Internet to search for material. Visualize, for the chosen locations, the tsunamigenic history, redrawing it and inserting it in your map, correlated with the relevant information obtained from the tsunami intensity scale provided.	*ThingLink* (for interactive maps) Word processor (for the tsunamigenic history diagram) DRIVE (for the final product)	60′ 15′ 5'

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	(The final product will be realized by small groups of 4-5 students, in order to have at the end a collection of interactive maps representative of the entire Sicilian and Calabrian coasts. They can underline the importance of the tsunami phenomenon in that area, to be emphasized in the debriefing). *Each group of students put the final product into a folder in Drive so that the shared document allows for immediate discussion of the results.*		
DEBRIEFING PHASE	**Assessment and Discussion** *The teacher* critically analyzes the output of the students, selecting a few tsunamigenic maps, asking the students to present them, explaining the reasons for their choices; the teacher corrects final products; makes suggestions and actively participates in the collective discussion, clarifying the appropriate conclusions and highlighting what is most important and dwelling on misconceptions about tsunamis. *The students* analyze the results and they reflect on their own final products and on those of their peers, making observations on the different products. Metacognitive thinking is being developed, resulting from discussion with others, about their final products and the way in which it was carried out. **Output** Corrected digital works can be shared and posted on the Drive folder.	Notepad (to write conclusions) DRIVE (to archive the final report)	30'

Due to the large number of participants in the special event described in *paragraph 2.2.1.*, it was difficult to manage the timing of the final live debriefing day. Indeed, it was necessary to give voice to all the 58 groups of students who had presented their products to their peers and discuss them with the researchers.

In response to the huge number of participants in the tsunami *ESL*, the appointments of the second live streaming on the occasion of the World Earth Day 2021 were doubled, separating the students of the 60 classes of the Middle school from the students of the 47 classes of the High school. Therefore, the INGV researchers conducted two second live streaming dedicated to the *debriefing* phase on 22nd April 2021, in which researchers and students discussed the results obtained for a constructive comparison and exchange of experiences of the participating classes.

3. Results

In a context of fast socio-cultural transformations, teaching must adapt, embracing the new educational needs through new ways of engagement and learning towards a positive outcome. This need was particularly evident during the Covid-19 Pandemic when it was necessary to combine the traditional frontal classroom method with *e-learning* [33]. Some activities that would have taken place in the classroom, moved online by means of mobile systems (smartphones, tablets) and technology played a very important role, not only in supporting frontal lessons, but also in favoring interaction remotely and in providing online resources [34]. In this particular historical period it was necessary to explore new ways of using digital teaching methodologies, such as *ESL*. This method, based on the *Flipped Class* model, has a teaching approach focusing on emotional, cognitive and behavioral components. The students autonomously acquire new information at home and, then, with their teacher and schoolmates, they rework, share and discuss their assignments [35]. Our experience in using the *ESL* method applied to Geosciences at schools highlighted that this approach could be an effective way to enhance motivation and learning, developing positive emotions and favoring higher levels of self-efficacy [36,37]. This is an opportunity to train students' skills in an active and participative environment. The low level of perceived anxiety in students also improves their learning [38]. Indeed, this method works in *real life* context, in which learning occurs in everyday situations and not only in dedicated teaching environments. The didactic becomes more experiential and reflective, providing meaningful learning. This contest improves the teacher-student relationship and grants teachers the necessary conditions to an effective and authentic assessment, observing students during all the three phases of *ESL* [39].

To celebrate 10 years of the method, the Catholic University of Brescia organized the "*ESL* Day", titled: "Gli *EAS* tra didattica e pedagogia di scuola - 10 anni di metodo" ("*ESL* between didactic and school pedagogy - 10 years of the method"). On this occasion we were invited by Prof. Rivoltella to present a lecture on our *ESL* experiments in Earth science disciplines, as we were pioneers in the application of the method in teaching Geosciences and Geophysics.

Sharing the experiences of the students from all over Italy in a period when everyone was homebound due to the Pandemic was the strength of the activity.

Concerning "*Earthquakes: history teaches us the future - researchers for a day with experimentation in didactics for ELS"* we collected many warm and enthusiastic gratitude comments from the students as they felt like a community, able to learn in an active and cooperative manner. Among the many testimonies of satisfaction, the most impressive from High school students are:

"An interesting and useful project on a subject about which people are often misinformed and underestimate the risks. It gave us the opportunity to learn how to reduce natural hazards".

"We were able to learn new and interesting topics, and at the same time we learnt how to work together in the most effective and efficient way".

"This activity allowed us to know earthquakes in a different way from the scholastic one, certainly more engaging, giving us a creative stimulus. I was fascinated to learn how a historical seismologist works".

"This project was really interesting both because it was different from all the others, and because of its practical approach. We used new digital tools to manage earthquake data working in teams. It was fun and made the work less burdensome, even dealing with a very delicate subject. I hope to do similar activities soon".

Not to mention the numerous appreciative e-mails from the teachers involved in the activity. Similarly, this positive trend was also highlighted by the answers to the questionnaires distributed to students and teachers after the learning activity.

Also as regards "*Tsunamis: history teaches us the future - researchers for a day with experimentation in didactics for ESL"*, we have collected many very appreciative posts from participating schools and reports in the *Noi MAGAZINE,* supplement of the *La Gazzetta del Sud* dedicated to education. In the related TGweb the students reported about their experience like "little journalists". Here are two of the most significant comments received from teachers:

"It was a stimulating and engaging initiative that let the students be protagonists and induced them to ask questions and look for answers, as researchers do".

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"A fruitful and exciting activity that puts students at the center of their learning process, making them the protagonists of their own education. An opportunity to experience a conscious and responsible use of new technologies".

At the end of each *ESL* activity, we conducted a survey by providing a satisfaction questionnaire, different for teachers and students. The feedback was very useful in assessing the perception and appreciation of our educational proposal and they guided us in the design of new learning activities. The answers received, in fact, confirmed the high appreciation and interest of both students and teachers. The following figures (from Figure 4 to Figure 9) show the results of the satisfaction questionnaires administered.

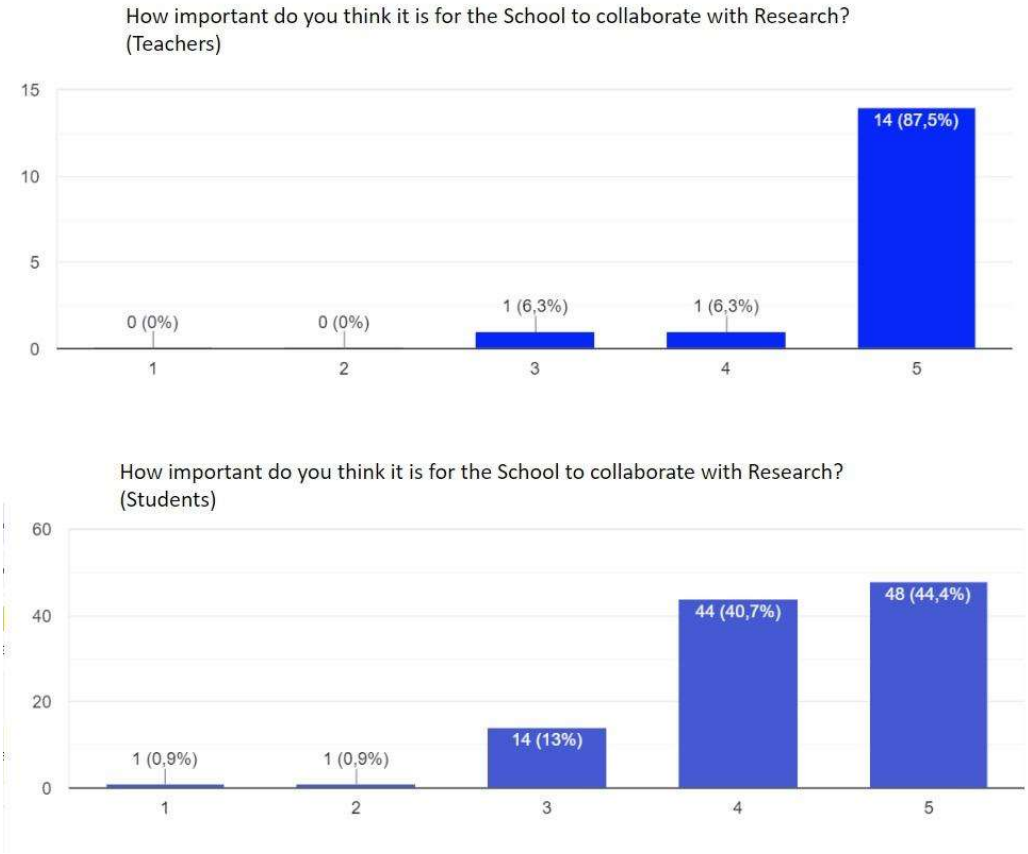

Figure 4. Cumulative values showing percentage of the feedback received for the first question from teachers (a) and students (b), concerning the ESLs experimentation.

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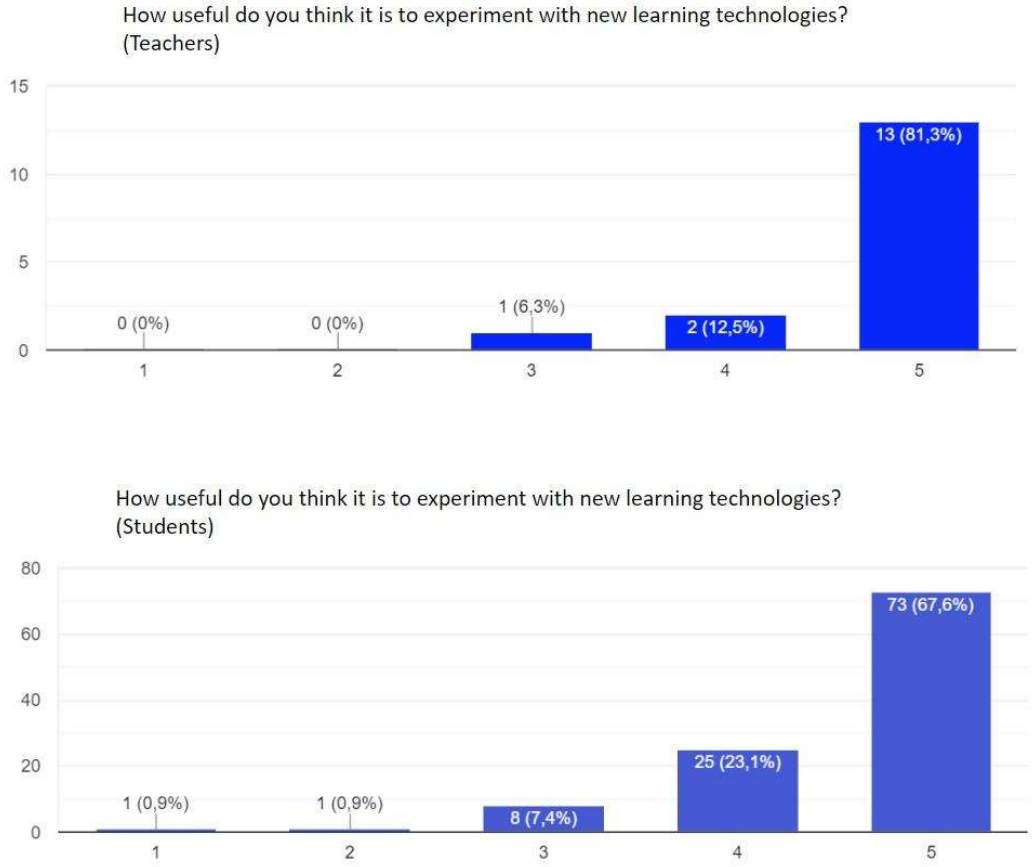

Figure 5. Cumulative values showing percentage of the feedback received for the second question from teachers (a) and students (b), concerning the ESLs experimentation.

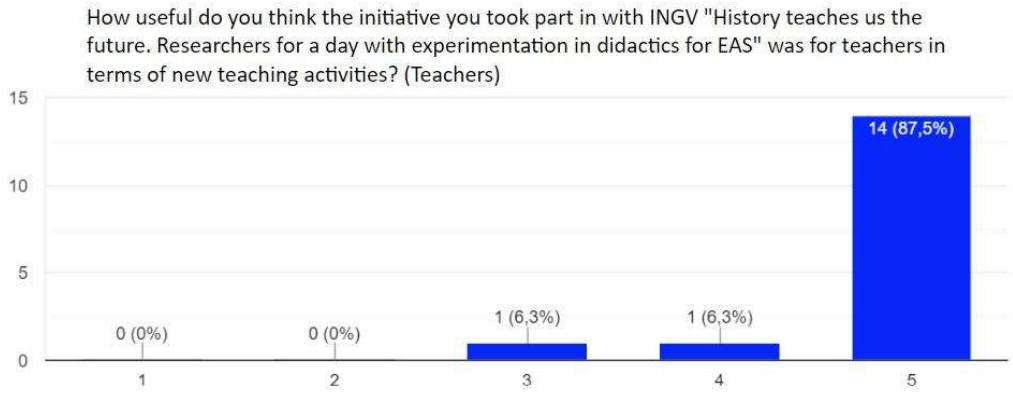

Figure 6. Cumulative values showing percentage of the feedback received for the third question from teachers, concerning the ESLs experimentation.

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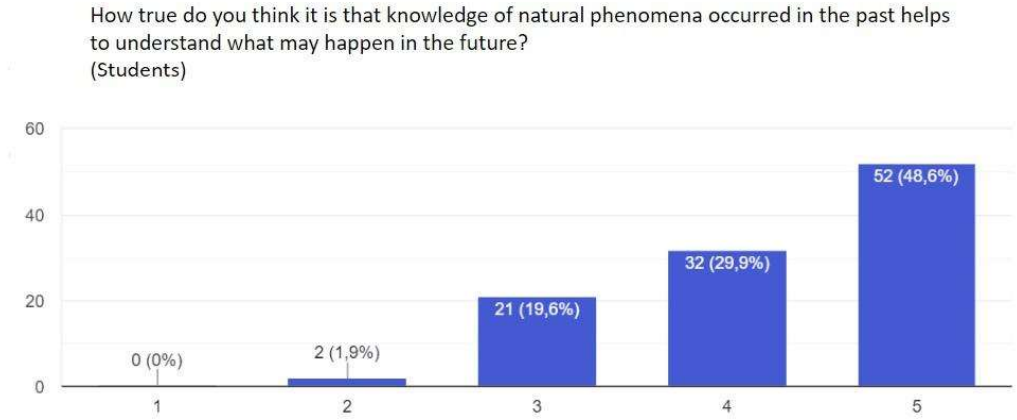

Figure 7. Cumulative values showing percentage of the feedback received for the third question from students, concerning the ESLs experimentation.

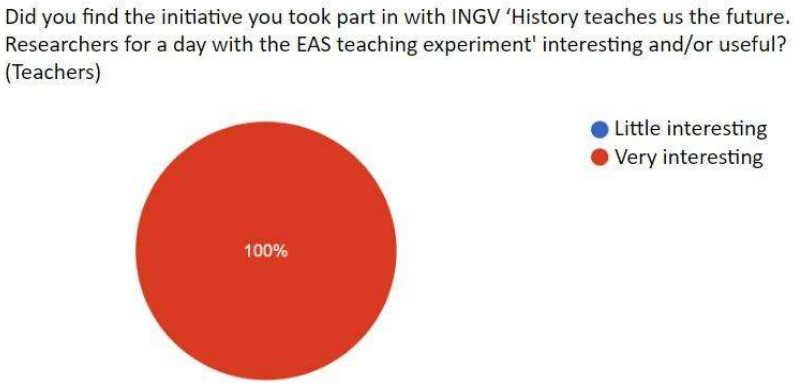

Figure 8. Pie chart showing cumulative percentage of the feedback received for the fourth question from teachers, concerning the ESLs experimentation.

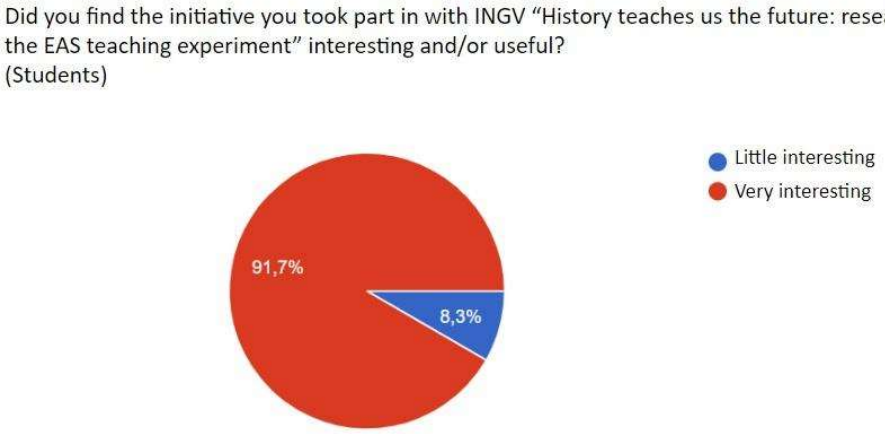

Figure 9. Pie chart showing cumulative percentage of the feedback received for the fourth question from students, concerning the ESLs experimentation.

The *ESLs* tested during the Pandemic allowed us to reach a very high number of students and teachers simultaneously connected on the web, improving the interaction between School and

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Research in that difficult period. The encouraging feedback received by the satisfaction questionnaires from all participants have proved the educational efficacy of the designed *ESL*s.

In the frame of the 90th Congress of the Italian Geological Society "Geology Without Borders" held online in September 2021, a talk titled "Experiments of e-learning: ELS (Episodes of Situated Learning) during the Pandemic" was presented. As a result of this presentation the University of Pavia proposed us to experiment with didactics for ELS inside the Path for Transversal Skills and Orientation (PTSO). The activity was conducted in distance learning during the first phase and the debriefing phase was held in person. The resulting blended (or hybrid) learning was an integrated teacher (in this case researcher)/learner approach strategy in a mix of different learning environments [40].

Future developments include the design of new *ESL*s on scientific topics, both in the field of Earth Science and Geophysics and in environmental issues, such as the last realized on request for *GeothermiX 2023*. This *ESL* deals with Geothermics in Italy, showed by a *ThingLink* interactive map and it was presented within the keynote speech titled "Experiments in innovative Geosciences Education through Episodes of Situated Learning (EAS) as interactive teaching tools for modern School: the case of Geothermal and Geo-resources" at the *GeothermiX 2023* conference held in Pisa in November 2023.

4. Discussion

ESL proposes an innovative way of studying with the use of new technologies, as a new way for teaching and learning. Experiencing *ESL* with 13-18 year old students let us know that a good *lesson plan* for this method can foster the development of *critical thinking*. The activities are designed to support authentic language use and to develop a type of thinking that involves making fair, careful judgements and evaluations based on evidence, reason, reflection, and open-mindedness. In a few words, how to teach learners to analyze complex settings [41]. Students have to understand the core problem and suggest solutions through the creative assembly of cultural objects [42]. An *ESL* is a "simplex" strategy, creating connections between *real life* and didactics, helping students to find simple tools that aid their learning to cope with complexity and to develop students' skills by means of devices [43]. The term "Simplexity"originates from the biological strategies through which living species adapt themselves to the surrounding complexity. The set of solutions to deal with different situations consider past experiences and anticipate future ones. These are new ways of addressing problems so that actions may be taken quickly and efficiently [44]. The trigger of this process to simplify principles for a complex world is the philosophy behind *ESL* that is "Say a lot in a few words and, if possible, make people think more than they say" [45]. Indeed, in order to create a digital communication product for their peers, students must acquire the ability to focus on the key concepts of the studied topic, reworking and understanding them in a deeper way. An example is the *ESL* named "*Earthquakes: history teaches us the future: researchers for a day with experimentation in didactics for ESL''*, in which the students discover the difference between the *microseismology* (analysis of the seismic signals) and the *macroseismology* (damage estimate). Under the guidance of the researchers, students understand how multi-faceted the seismologists' work is: it can deal with different branches of seismology, studying the various aspects of earthquakes for a greater understanding of the Earth system as a whole. During the second phase of the *ESL*, to enrich the final macroseismic map with further information about the chosen earthquake, the students surfed the web and analyzed parts of original texts describing the earthquake's effects, images and historical maps. In this way, they were able to identify themselves in the work of the historical seismologist, performing an engaging educational activity.

According to Howard Gardner *theory of multiple intelligences* [46,47], people do not have just one intellectual capacity, but have many kinds of intelligence that must fulfill eight criteria: visual-spatial, linguistic-verbal, logical-mathematical, body-kinesthetic, musical, interpersonal, intrapersonal and naturalistic. Many teachers use multiple intelligences in their teaching to integrate Gardner's theory into the classroom. In relation to all this, one of the strengths of the *ESL* method is to develop *active learning* in which students feel free to express all their abilities [48]. One of the most relevant benefits

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of the *ESL* method is, in fact, that it allows the student to use his/her own intelligence in the respect of everyone's identity [49]. Each student might be particularly strong in a specific ability, so that in a classroom a wide range of different talents is available [50]. *ESL* is a methodology particularly suitable for the study of natural hazards, in order to promote the spread of good practices, fostering the development of *emotional intelligence*, that is the secret of well-being when the right and left part of the brain are in equilibrium. Daniel Goleman describes *emotional intelligence* as understanding and managing your own emotions and influencing the emotions of others [51]. Examining the interpersonal and intrapersonal aspects, human intelligence is deeply linked to the social and affective dimension of every human being's life. *ESL* is the didactic methodology able to put into practice that creativity found between rational and emotional thinking. And thanks to creativity, students learn spontaneously in a friendly climate. The advantages of flipping are to promote peer interaction and collaboration skills in order to make learning central rather than teaching, to foster independent learning, to encourage higher student engagement, and to provide increased individualized attention [52]. The *ESL* model leads to higher levels of scholastic engagement in students and reduces their level of perceived anxiety. Moreover, this method facilitates the embedded assessment activities, thanks to assignments, and exercises about a particular learning outcome. Indeed, the evaluation is formative: it is not only the mere vote on the students' final digital creative product, but it is the result of the teacher's observation during all the three *ESL* phases. The assessment encompasses the behavior of the student who, independently and in groups, works on a project and then presents to others its product. The teacher can evaluate the students' work, using an **assessment rubric**, designed as an *ad hoc* summary statement describing competence and indicating the degree of achievement of the set objects. The synthetic outlines of the **declination of competences grid,** are a further detailed evaluative tool to have an objective evaluation criterion, pointing out which parameters are to be considered in the evaluation. This type of evaluation lets teachers know the students' skills within a particular domain (i.e., social, academic) favoring future *lesson plan*s to support the student's progress [53]. Moreover, it is a way to discover if the designed learning activity is effective. *ESL* needs a careful teacher's designed *lesson plan* to create situated and meaningful learning experiences, leading students to realize digital artifacts, fostering a personal appropriation of content. The effort of finding suitable video stimuli and learning trigger activities, takes a lot of time and sometimes discourages teachers, who have to surf the web, to design creative activities through free apps, addressing students' self-production activity [54]. Therefore, teachers particularly appreciate finding ready-to-use *ESL*s on topics of their interest to perform with their classes. The *ESL*s experienced during online meetings with INGV researchers (*informal learning*), focussed on *microlearning* activities to achieve self-production starting from *real life* (knowing the seismological setting of a student's own area, which is a crucial factor in seismic hazard reduction). This is placed in a context that gathers together knowledge, skills, attitudes and competences. Students learn better if they start from situations of daily life or setting in their territory, in which they can focus their attention, acting on *microcontents* developing *thinking skill*, *problem solving*, and *reflective learning* [55]. The situated education action as a minimum, but significant, unit is a clear example of how it is possible for teachers to work with *ESL* in the virtual classroom with students at home connected by web and not only in presence [56]. Indeed, the *ESLs*. experiments of the series "*History teaches us the future: researchers for a day with experimentation in didactics for ESL*", are two examples of digital teaching of Geoscience, created to help students and teachers during the Pandemic. They perfectly fit with the INGV mission to spread Geophysics research results. This activity is not a mere dissemination and communication: it's education [57]. And it is also a way to bring future responsible citizens closer to researchers' work and making students aware that public research is at the service of Society. Research and School can do a lot together, focusing on protection, knowledge and awareness on natural disasters prevention and they can encourage good practices and safe and sustainable behavior [58,59,60]. This is a way to build resilience at school involving students, teachers, school leaders and families too, because the youth can be a precious vehicle to make adults aware [61].

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