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Brief Communication - ALARM: an innovative protocol of educating on seismic risk perception, and its assessment

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Abstract
The effectiveness of risk mitigation depends also on how well-prepared and informed society is about the risk itself. The younger generation plays a key-role in the scientific awareness of society, representing both the future of society, and a conduit to reach and educate their families. We developed a didactic experience, based on Serious Games, dedicated to seismic risk that was tested and then implemented during the whole COVID19 pandemic.
Before the start and at the end of any of these activities, an evaluation phase was carried out to assess the learning experience and the effectiveness of the science communication technique.

1. Introduction

Science and its perception are of fundamental importance for the resilience of our society. COVID19 has been a huge "alarm bell" in this sense: the societal reaction to science, and the trust citizens have in it, highly depend on how scientific results are communicated (Reuter and Spielhofer, 2017; Reuter et al., 2019; Appleby-Arnold et al., 2021; Mitchell et al., 2008).
It is therefore crucial to develop new strategies and protocols to communicate science and risk (Belser et al., 2018; Kikas et al., 2009; Fernandez and Shaw, 2013; Musacchio, G. and S. Solarino, 2019).
From the geological point of view, Italy is one of the most complex, hazardous, and therefore scientifically interesting country in the world, characterized by high seismic hazard. In particular, focusing on Campania region (Southern Italy), this area was struck on 23rd November 1980 by one of the strongest seismic events in Italy (the Irpinia earthquake, M_W 6.9). It becomes thus of fundamental importance educating and informing about the concept of risk in general, and specifically seismic risk (Dallo et al., 2022). Furthermore, the younger generations play a key role in the scientific awareness of society, representing, on the one hand, the future of society and, on the other hand, a conduit to reach and educate their families. Nonetheless, when dealing with younger generations, one has to be careful with setting up the correct language and to make them feel involved in the experience (Musacchio et al. 2019).
In this perspective, the use of Serious Games, training tools in which serious and playful aspects are ideally balanced, which is certainly an innovative practice in science communication (Fotaris and Mastoras, 2019; Lathwesen and Belova, 2021; Lopez-Belmonte et al., 2020; Veldkamp et al.,2021), is gaining momentum since it favours participants' learning through their active involvement in the experience.
We developed an educational protocol dedicated to high school students that combined a seminar on the basic concepts of seismology and seismic risk education with a serious game that would allow

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students to assimilate the content while keeping the overall experience light and interactive, and the learning informal.
Our goal was to allow the students to be at the centre of the action while not only learning the scientific content but also developing problem solving and leadership skills.
The experiences were, then, repeated in different contexts with classes from different parts of the region, using different platforms. The results allowed us to better understand how to customise it for different targets and situations. Finally, we developed an evaluation protocol with the aim of assessing the impact of the use of our protocol when communicating and teaching the concept of seismic risk on both risk perception and interest towards science and geophysics. This paper focuses on the results of such evaluation.

2. Methods

In the following we will describe the protocol, the data used to perform the analysis and, finally the methodology applied to analyse the collected data.

2.1 Protocol

Our protocol, which targets secondary school students (15-18+), consists of a frontal lecture part (1h) and an innovative teaching part based on the use of a virtual escape room called ALARM (1h), a crossword for eArthquake, heLp, mAgnitude, epicenteR, seisMologist. An escape room is a game in which a team of players discover clues, solve puzzles, and accomplish tasks in one or more rooms to reach a specific goal in a limited amount of time. The goal is often to escape from the site of the game. In a virtual escape room, the “room” can also be figurative. Most escape games are cooperative but competitive variants exist.
The number of simultaneous participants of the protocol oscillated in a range between 15 and 60 pupils. For them to interact with in the Serious Game we used a platform for online pools. The platform in which the videoconference was set is Google Meet (The use of a specific platform in this case was related to a choice of the participant schools because of privacy policies, nonetheless many others videoconference platforms are feasible).
The frontal lesson is dedicated to the basic topics of seismology such as the definitions of earthquake, seismic waves, focal mechanisms, seismic risk, and the Italian map of hazard. During this part of the protocol, pupils are given tools and keywords to solve riddles and puzzles of the following escape room. On the other hand, the escape room single enigmas are customized on the targeted pupils and their academic and social background.
In this way, the protocol allows students to acquire both specific topics, such as the physical quantities of an earthquake, e.g. location and magnitude, and general concepts, such as the perception of seismic risk and the impact of man in the prevention, in the possible induction and in the response to an earthquake.
In our case, participants acquire basic concepts of seismology, learn the basic techniques for locating an earthquake and determining its magnitude. They are given tasks and missions that they can only solve with the knowledge they will gradually discover during the game. Moreover, the virtual character of the activity makes it inclusive towards motor disabilities.
In the tuning phase, ALARM has been replicated in different contexts with classes from different parts of the region and through different platforms (also for ethical/legal reasons due to the presence of minors) with general and specific results.

2.2 Data collection and analysis methodology

Before and after the practices, students and teachers were submitted a form to assess, on the one hand, the preliminary status of knowledge and interest and the expectation on the experience; on the other

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hand, the impact of the event. The form was a google form on which every pupil could access only once form his/her own personal device by scanning a QR code. Due to the pandemic the students were each one in his own house and thus we can presume they did not exchange each other information concerning their answers, given the amount of time they were given to answer the forms and the goodwill of the participating pupils.
Data were collected using anonymisation, furthermore no personal sensitive data (age, gender, religion, etc) were used and collected if not in aggregated form. Nobody was obliged to respond to any of the question if it could in any sense offended them.
The evaluation form consisted in multiple choice, Likert scales and open questions. The Likert scale (Likert, 1932) is a psychometric scale commonly used to derive the attitude towards the given object, event, or concept. Respondents make a choice on a numerical scale that we set from 1 to 5.
While the multiple choice and the open questions were used to allow more personal inputs which were considered as qualitative results of the investigation. A test group experienced the protocol reversed, i.e. virtual escape room followed by the frontal lecture, to evaluate the effect of the inversion.
To assess whether the pupils have assimilated the concepts proposed in the protocol, it is useful to evaluate the statistical correlation of the answers before and after the experience, via a t-Student test (Student, 1908) with a hypothesis on the significance of the distribution difference. In fact, 99% probability and 112 degrees of freedom corroborates the significance of all the mean values differences of the answers before and after the training section. To ensure internal consistency of data and retrieve how closely related is a set of variables of as a single indicator, we verified the Cronbach alpha of all the data sets. Such measure allows to use the mean values of the Likert scales to compare the before and after results. Finally, the effect of the inversion on the test group was investigated via a Chi Quadro test, with a rejection of the null hypothesis for $p<0.05$.
112 students participated in ALARM of which 15 experienced the protocol reversed. 93% of the students are minors 15 y.o. (3%), 16 y.o. (47%) and 17 y.o. (43%), while the rest 7% is 18+ y.o.. Gender wise the participants were almost twice as many females (63%) than males (34%), with 3% not revealed. It is also clear that most of the students (96%) were not familiar with recreational or educational escape rooms before this experience. Among the 4% of the students who had previously participated in a Virtual Escape Room, only 1 had joined a recreational one, the rest had already experienced a didactic/educative one.

3. Results

To ensure internal consistency of data and retrieve how closely related is a set of variables of as a single indicator, we verified the Cronbach alpha, of all the data sets, i.e. Group 1 – pupils who experienced the direct protocol; Group 2 – pupils who experienced the inverse protocol; Group 3 – all the pupils; Group 4 – 15 randomly selected pupils from Group 1.

Table 1 - Cronbach Alpha results

Phase	Group	Cronbach Alpha	Phase	Group	Cronbach Alpha
PRE	1	0.72	POST	1	0.71
PRE	2	0.71	POST	2	0.85
PRE	3	0.73	POST	3	0.75
-	-	-	POST	4	0.71

As showed in Table 1, the obtained results (Cronbach alpha>0,70) indicate a large correlation and large consistency between the indicators.
Such measure has allowed to use the mean values of the Likert scales to compare the before and after results.

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3.1 Pre vs Post : Group 3

In the following we will display the result obtained by confronting the pre and post evaluation for Group 3: all the pupils.

3.1.2 Quantitative Results

To assess whether the pupils have assimilated the concepts proposed in the protocol, we evaluated the statistical correlation of the answers before and after the experience, via t-Student test with a hypothesis on the significance of the distribution difference for Group 3. The results are shown in Table 2.

Table 2 - t Student test result for Group 3 comparing pre and post protocol

	PRE		POST		p value
	μ	**σ**	**μ**	**σ**	
Question A	3	1	3,6	0,9	**0,0002**
Question B	2,6	0,9	3,3	0,8	**5E-10**
Question C	2,6	0,9	3,3	0,8	**8E-08**
Question D	2,7	0,9	3,3	0,9	**1E-07**

For all the questions in exam the test results in the rejection of the null hypothesis with 99% probability ($p<0.01$) and 112 degrees of freedom, corroborating that there is a significant divergence between the two distributions, i.e. pre and post protocol.
It is interesting to see what this difference implies for each question.

- Question A - How much and how do you think the telematics mode will affect the experience?

The Likert scale was set from 1 (very negative impact) to 5 (very positive impact). The pre protocol mean value is set on 3 (null impact) while the post protocol mean value is 3.6 (null to positive impact). Which hints to the fact that the use of the Escape Room, which would not be possible in a live setting with the same amount of people, was considered as a positive feature.

- Question B - How would you rate your knowledge of earthquakes?

The Likert scale was set from 1 (very low knowledge) to 5 (expert knowledge). The pre protocol mean value is set on 2,6 (lower than average) while the post protocol mean value is 3.3 (higher than average). Which hints to the fact that the students perceived the protocol as effective and a learning experience.

- Question C - How would you rate your awareness of your region's seismic risk?

The Likert scale was set from 1 (very low awareness) to 5 (very high awareness). The pre protocol mean value is set on 2,6 (lower than average) while the post protocol mean value is 3.3 (higher than average). Which hints to the fact that the students perceived the protocol as effective in communicating the concept of seismic risk.

- Question D - How interested are you in geophysics?

The Likert scale was set from 1 (very low interest) to 5 (very high interest). The pre protocol mean value is set on 2,7 (low to null interest) while the post protocol mean value is 3.3 (null to high interest). Which hints to the fact that the protocol had a positive impact on the pupils' interest in science and geophysics.

3.1.2 Qualitative Results

The post protocol questionnaire had three more questions, whose answer we report in the following.
To test the students' perception of their own learning in the overall experience, we asked them about what educational goals they thought they achieved with the escape room.
Students perceived the overall experience as positive not only in the acquisition of new content knowledge and skills but also in elaborating and testing on previous and acquired ones.

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Around 20% of the pupils have found the experience as team building and as a booster in the motivation to further undergo studies of geophysics. A little more than 5% of the students have found the experience as a formative assessment.
Moreover, to test the likeability of the protocol for, we used standard marketing questions for retention and advocacy considering our protocol and "the product". The protocol obtained a 98% of retention and a 94% of advocacy.

3.1 Direct vs Inverse protocol: Group 2 & 4

In the following we will display the result obtained by confronting the direct and inverse protocol post evaluation for Group 2 – pupils who experienced the inverse protocol – and Group 4 – 15 randomly selected pupils from the ones who were subject to the direct protocol.
We applied Chi Quadro test to Group 2 and 4, with a rejection of the null hypothesis for $p<0.05$ (95%). Table 3 shows the results.

Table 3 - t student and X^2 test for post results of Group 2 and 4

	Group 4		Group 2		χ^2
	μ	**σ**	**μ**	**σ**	
Question A	4,0	1,1	3,4	0,7	0,40
Question B	3,7	0,8	4,0	0,8	0,98
Question C	3,2	0,7	3,6	0,6	0,93
Question D	3,5	0,7	4,1	0,7	0,93

Both tests fail to reject the null hypothesis with the significance we have chosen to be valid (95%) and therefore it is not possible to conclude that the two distributions (for each question) significantly differ.

4 Discussion and conclusion

We developed an educational protocol dedicated to high school students (15-18+) that combined the theoretical phase with a seminar on the basic concepts of seismology and seismic risk education with a serious game that would allow students to assimilate the content while keeping the overall experience light and interactive, and the learning informal. By using the evaluation protocol, we managed to assess the impact of our protocol when communicating and teaching the concept of seismic risk on both risk perception and interest towards science and geophysics.
The results are very encouraging and show that the students perceived the protocol as effective and a learning experience both in the basic concepts of seismology and in the risk perception. The protocol had, also, a positive impact on the pupils' interest in science and geophysics. Among the qualitative answers of the evaluation forms, in fact, many students referred to the realization of how close this topic or science in general is to everyday life, hinting at a growth in the Science Capital of the participants.
We also investigated the effect of an inversion in the protocol, i.e. the Escape Room was played before the seminar, allowing the pupils to experience first what they would learn later. In this case the results were, as expected, not significant. On one hand, in fact, our protocol is too short to allow a full development of an Inquiry Based Learning (IBL) methodology, on the other hand, the test group with which we were able to test the inversion was little. For these reasons, a deeper investigation of the inversion consequences could be a future step of this research.
In our believes, one of the factors that helped the success of the protocol was the age of the selected target. In fact, the developed puzzles and the discussed topics need a level of consciousness of both

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mathematics and logic that is generally developed in high school. (Kikas et al., 2009; Lefa, 2014; Ojose, 2008).
Possible further developing of the protocol can investigate the impact of gender, socio-economic context and psychological factors possible influencing the results.
Another possible feature to investigate is how the number of simultaneous participants impacts on the efficacy of the protocol.

5 Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

6 Author Contributions

MVG and FN performed the data collection and analysis. MVG, FN and OA conceived this work. MVG, FN, RR and OA were involved in the interpretation of results. MVG wrote the paper. PC provided funding for this work and coordinated the working group. All co-authors were involved in the review of the manuscript.

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