

Tsunami at school. An experimental strategy to increase students' risk perception

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Abstract

We tested a methodology for assessing high school students' tsunami risk perception and knowledge to improve their tsunami awareness. Our objective was to test whether the use of a structured questionnaire on tsunami risk perception could be used as a tool to assess students' improvement after a lesson on tsunamis. For this purpose, we involved about 100 students from four classes of a high school (Polo Liceale Statale "Lazzaro Spallanzani") in the town of Tivoli, in central Italy, about 20 km from Rome and 40 km from the seaside. We administered the questionnaire in three subsequent surveys (to 94, 96, and 109 students, respectively), the first of which without providing any information on which subject they would be dealing with. Students were asked to answer the 31 questions individually, each using her/his mobile phone during science class. After two months, all four classes were trained with a frontal lesson and a discussion on tsunami risk. Afterwards, we administered the questionnaire again and ran the second survey. Finally, we met the students one year later and administered the questionnaire again, then we compared the three survey results. The comparison shows that the students' risk knowledge and perception, which was generally very low in the first survey, improved significantly after the lesson and the relative discussion. Although this result was somewhat expected, it has been possible to confirm and quantify the improvement. According to studies conducted using similar methods [Gray and Di Loreto, 2016; Ayllón et al., 2019], the active participation of students, the collaborative approach provided by teachers and researchers, and the use of a survey tool such as a questionnaire – which, despite being completed individually, fosters an environment of emotional sharing – all contribute to stimulating students' curiosity and facilitating their learning in traditional educational settings. We then administered the questionnaire to the same classes one year later. The outputs of the third survey show a partial decrease in students' awareness that nevertheless remains significantly better than in the first survey. This suggests that the students' involvement in the learning process through the questionnaire and through an active discussion after watching videos and pictures works well, but also that a periodic reminder by the science teachers is needed to maintain a constant level of risk awareness and perception. We propose to replicate this approach by involving teachers in the survey, providing them with a recorded lesson with all the basic elements, to be shown between the first and second administration of the questionnaire, and with periodic (yearly) reminders.

Keywords: Tsunami; Education Tool; Risk Communication; School; Risk Mitigation

1. Introduction

The Mediterranean region is affected by tsunami hazard, as witnessed by several historical events documented by the Euro-Mediterranean Tsunami Catalogue EMTC. Almost 90% of the reported tsunamis were due to earthquakes, the remaining 10% were due to volcanic eruptions or flank collapses, and landslides [Maramai et al., 2019; Selva et al., 2021a]. For seismically generated tsunamis, the probabilistic tsunami hazard model released by the project TSUMAPS-NEAM for the whole North-Eastern Atlantic, Mediterranean, and connected seas region [Basili et al., 2021] shows the regions with the highest hazard. These include the Eastern Mediterranean countries and Southern Italy, where some important events occurred in the past. These include the 1908 Messina-Reggio Calabria tsunami [Platania, 1909; Baratta, 1910] generated by a M7.1 earthquake, and the 2002 Stromboli tsunami [Tinti et al., 2006]. Several other events are documented for the Italian coasts, mostly in the Ionian Sea, but also in the Adriatic, the Tyrrhenian, and the Ligurian Sea [Maramai et al., 2014].

However, tsunami risk is underrated by Italian citizens, including those residents in high-hazard coastal areas, due to the low frequency of such events and the long time elapsed since the last relevant event in many regions of Italy [Gravina et al., 2019; Cerase et al., 2019; Cugliari et al., 2022a]. Similar situations have been documented in several other areas of the world, with a few exceptions relative to countries where tsunamis are very frequent and/or where a damaging event has occurred in the recent past [see Cugliari et al., 2022b for a review]. The importance of the collective memory of past events, information campaigns, and drills as well as the presence of signs indicating correct behavior and evacuation routes, have proved to be of great importance in increasing risk perception and responsiveness [Weinstein, 1989; Becker et al., 2008; Mercer, 2012; Chen et al., 2022; Cerase and Cugliari, 2023]. In Italy, especially for the younger generations, this seems to be limited by poor school education on natural hazards, by the lack of civil protection plans that include tsunami risk (and, when available, of their limited diffusion in the population), and by the poor dissemination of scientific culture on natural hazards and related risks.

Our research hypotheses are based on the findings of Cerase et al. [2019] and Cugliari et al. [2022] in which the authors tested an intervention methodology applicable in various learning contexts. The first research hypothesis (RH1) assumed that the students have a low tsunami risk perception and poor phenomenon knowledge, as suggested by the results of a national sample surveyed in the two cited studies. Secondly, we hypothesized (RH2) that interactive lessons, using multimedia support material extensively and open exchange of opinions, are effective with teenagers. This teaching strategy aims to keep the lecture engaging and promote active learning [Johnson and Johnson, 2005]. Lastly, we wanted to test (RH3) whether students, given the laboratory character of the lesson and the simple concepts conveyed through familiar media, maintain a significant amount of knowledge through time.

We adopted a slightly modified version of the questionnaire adopted by Cerase et al. [2019] and Cugliari et al. [2022a] consisting of 27 questions organized in 6 sections, alternating between closed questions and others with a 5-way Likert scale (from strongly disagree to totally agree). For this specific assessment methodology, we removed section 5 of Cerase et al.'s original survey, the one on cultural attitudes and worldviews, adapting it to a non-coastal area, as described below. We removed several contextual items e.g. "*How many kilometers away from the coast do you live?*" and: "*Do you think the coastline of the municipality (or province) where you live could be hit by a tsunami?*" or "*for how many generations has your family lived on this stretch of coast?*" [Cerase et al., 2019; Cugliari et al., 2022a] turning them to more general questions such as "*do you think the Italian coasts could be hit by a tsunami?*", or "*In your opinion, which Italian regions are most likely to be hit by a tsunami?*". Moreover, in the final part of the questionnaire we added two open-ended questions (the first short answer, the second long answer) to survey whether the students wanted more information on natural hazards and, if so, how they prefer to receive it. Finally, we asked their opinion on the best method to raise awareness of and prevention of natural hazards.

To focus the objective of this study and to analyze students' tsunami risk perception from a longitudinal perspective (pre- lecture – post- lecture and one year after the first lecture) [Ruspini, 2002; Moreno and Shaw, 2018], we chose the following 5 target questions from the questionnaire:

- 1) Do you think the Italian coasts can be hit by a tsunami?
- 2) Which Italian regions do you think are most likely to be hit by a tsunami?
- 3) Do you think that a 50 cm tsunami can drag an adult person?
- 4) Do you think it is possible to warn people before the arrival of a tsunami?
- 5) Through which communication channels would you like to receive a tsunami warning?

Research questions (RQs), better address issues related to tsunami risk perception, knowledge of the phenomenon and the channels through which students draw information and through which they would prefer to receive a tsunami warning.

The choice of RQs is corroborated by the results obtained on the national sample and discussed extensively in Cerase et al. [2019] and Cugliari et al. [2022a]. In section 3 we discuss the survey results.

2. The first survey at the Spallanzani High School in Tivoli

The town of Tivoli, with about 56,000 inhabitants [ISTAT, 2023] is in Latium (Latium region), in the Roman hinterland, about 40 km from the sea. Therefore, the town is not at tsunami risk and its residents are likely to have a limited knowledge of the phenomenon, as in general for most of the Italian population. Cugliari et al. [2022] studied risk perception in Lazio and other Italian regions, highlighting the generally low level of risk perception, with a tendency, for those who live far from the coast, to underestimate the specific risk. This information, however, cannot be generalized for the entire Italian territory since, in some contexts in southern Italy, the memory of past events is still present. In these contexts, tsunami risk perception is higher than in other areas of the Italian peninsula [Cerase and Cugliari, 2023]. This provides us with a further stimulus to extend the horizons of this survey also in micro-contexts composed of students and/or citizens who are potential tourists on Italian, European and world coasts.

It is worth saying that most of the interviewed students visit the seaside rather frequently, as many Romans also do, especially during the summer.

The Liceo Lazzaro Spallanzani in Tivoli has a science program, with three classes involved, every year, with a specific focus on Earth Sciences called *Curvatura Geologico-Ambientale*, created in 2018 in collaboration with the Roma Tre University with the support of the MIUR (Ministry of Education, University and Research). One of the authors of this article (LDF) is a geologist who has been teaching at this school since 2011.

In recent years, several didactic activities focusing on geology have been organized, including a volcanological field at Stromboli [2019] and a PCTO project (from 2018 to present, called *Mediterraneo Dinamico*), both supervised by LDF and the INGV researcher Tullio Ricci. However, when we organized the first survey (8 March 2022), no specific activities on tsunami hazard and risk, and tsunamis in general, had been carried out among the classes involved in the proposed study methodology.

We decided to involve in the study four classes (two third-year, one fourth-year and one fifth-year, corresponding to ages ranging between 16 and 18 years old). In each class, we were invited by LDF to intervene during science hours to administer the questionnaire. We asked the students to use their mobile phones to access the questionnaire implemented on Google web form via a QR code (see the appendix), only made available at the beginning of the hour, or by the link sent by the teacher to the WhatsApp group comprising all the students in the class (to extend the survey to students in distance learning).

The questionnaire required approximately 20 minutes to be completed. The survey process and closing were followed in real-time through the Google Forms/Excel table database and the results were available immediately after the collection. The procedure was repeated for all four classes. Immediately after the survey, we collected several questions from the students on the content of the survey, providing them with some initial answers to their questions and doubts on some specific topics (“Do you know the regions in the Mediterranean where tsunamis are most frequent?” “Which region in Italy is mostly at risk?” “Are there tsunami warning systems in Italy?” etc.).

The results show a general underestimation of tsunami risk in the Mediterranean and on the Italian coast. However, in the first survey, we found that more than 60% of students believe that tsunamis are likely to occur in Italy, suggesting better knowledge than the average Italian population. In fact, in a recent study on tsunami risk perception among the population living in coastal municipalities in eight Italian regions [interviewed using CATI – Computer Assisted Telephone Interviews – for a methodological review see Kempf and Remington, 2007], it emerged that 39% of the respondents believe it is likely that the Mediterranean coasts could be hit by a tsunami while, 36% of the entire sample believe it is unlikely that this could happen. The percentage of those who consider it unlikely to happen is higher in the national sample of the population (henceforth called Telepanel, i.e. a reference panel of over 1,000 citizens from all over the country who are involved from time to time in various surveys, including political, marketing, etc.). The result of this last survey shows that over 40% of the population considers it unlikely that a tsunami will occur in the Mediterranean Sea and only 19% consider it likely that a tsunami may hit the

Mediterranean coasts [Cugliari et al., 2022]. The two questionnaires (Telepanel and student questionnaire), in contrast to the questionnaire used for the CATI survey, have the same item wording. A few minor changes were made to both questionnaires to facilitate collecting the opinions of those who do not live in coastal municipalities. The results show a general underestimation of tsunami risk in the Mediterranean and for the Italian coast. However, in the first survey, we found that more than 60% of students believe that tsunamis are likely to occur in Italy, suggesting better knowledge than the average Italian population. In a recent study on tsunami risk perception among the population living in coastal municipalities in eight Italian regions (interviewed using CATI), it emerged that 39% of the respondents believe it is likely that the Mediterranean coasts could be hit by a tsunami while, 36% of the entire sample believe it is unlikely that this could happen. The percentage of those who consider it unlikely to happen is higher in the Telepanel. The result of this last survey shows that over 40% of the population thinks it is unlikely that a tsunami can occur in the Mediterranean Sea and only 19% consider it likely that a tsunami may hit the Mediterranean coasts [Cugliari et al., 2022].

We also found that more than 80% of students believe that only tsunami waves greater than 1 meter can be dangerous to individuals, showing that the risk from small tsunamis is underestimated, as also found for the national sample. Regarding the different risk attributed to the various Italian regions, there seems to be a relatively correct opinion, with southern Italian regions more exposed than northern ones, but with some biases probably related to stories heard in the media about underwater volcanoes in the Tyrrhenian Sea and to a lack of knowledge of past events in the younger generations living far from tsunami-affected areas. We observed an overestimation of the risk for Sardinia, probably due to its large size and its being an island, which could make it perceived as more exposed to marine hazards. This hypothesis was confirmed during the opinions exchange held with the students during the frontal lesson that took place in the second meeting (see next section). On that occasion, the students did not identify scientific evidence to support their answers, justifying the information provided with the assertion: *“We answered this way because it’s an island, we thought it was more exposed to tsunamis and consequently the risk was higher.”*

Finally, we asked students whether they believe that warnings can be sent to people before an imminent tsunami; only 56% of students answered “Yes”, while the others answered “No” or “Don’t know”.

2.1 The formation and the second survey

It took about 20 minutes for the students to complete the questionnaire in the first round. As soon as the questionnaire was completed, we encouraged the students to ask what impression they had of the questionnaire, what they were most curious about, and what they would like to improve. The students’ attitude towards the topic was generally of curiosity and surprise.

The students were impressed on how an under-recognized and, consequently, underestimated phenomenon in the Mediterranean area has been repeated several times over the years, also causing considerable damage.

The following questions are among the most frequently asked:

- A) Their concern and request for further information in case of a tsunami like the one that affected the Italian coast in 1908 being triggered today. What this would mean to the people living on the coast today and the impact on the facilities hosting tourists in the summer. We noted a strong concern on these issues by the students.
- B) We were asked several times if this phenomenon could relate to climate change. A legitimate question posed by students who have no specific knowledge tools in this regard, which highlights their worry about the climate change we are facing in recent years.
- C) Some students asked if there are any tools to mitigate the impact of a potential tsunami (referring, for example, to the retaining walls used in Japan or to the MOSE system implemented in the Venice lagoon to contain sea level rise when the “Acqua alta” phenomenon occurs). To these questions, scientific answers were provided that were congruent with their need for knowledge.

The survey tool was generally well accepted and no suggestions on the subject were asked by the students. However, they were mostly interested in learning about tsunami risk in Italy, on some historical events in Italy and Greece, such as the Messina-Reggio Calabria earthquake and tsunami of 1908, the Crete event of 365 AD, the more recent cases in the Aegean Sea (Kos-Bodrum 2017, Samos-Izmir 2020), and the Stromboli volcanic tsunami of 2002.

Two months after our first visit to the Spallanzani school, we went there again and met the same four classes' students during science classes (Fig. 1 and Fig. 2).



Figure 1. A moment of tsunami teaching at the school in May 2022, during the pandemic when it was mandatory to use protective masks.



Figure 2. Another moment of tsunami teaching at the school in May 2022.

In the first part, we did a frontal lesson on tsunamis, focusing on the following topics: a) the genesis of tsunamis; b) past and recent tsunami distribution worldwide and in the Mediterranean; c) the tsunami warning systems coordinated by UNESCO IOC (Intergovernmental Oceanographic Commission); d) tsunami impact in different cases;

e) the Italian tsunami alert center and the NEAMTWS; f) some examples of recent events in the Mediterranean. The lesson ended with some short videos on tsunamis, including some tutorials, the mega-tsunamis of Sumatra 2004 and Japan 2011, the 2018 Palu event, but also some “minor” cases in the Mediterranean, such as the Kos-Bodrum event (2017), and the Samos Izmir one (2020), less strong than the previous ones but closer to their experience of vacations in the Mediterranean islands and seas. These latter were shown to emphasize: i) the presence and relative frequency of moderate (6.5-7.0) tsunamigenic earthquakes in the Mediterranean, and ii) the danger raised by “small” tsunamis with a runup of 1-2 meters. In addition, a video showing an “artificial tsunami” in a pool (realized in Japan) was shown to point out the risk induced by tsunamis of about 0.5 meters: the image of a man dragged by the strong currents (seen from three different perspectives) revealed very powerful to explain why a 0.5 meters high tsunami wave is very different from, and more dangerous than, a normal sea wave (Fig. 3).

We will see later in this section how these videos and the related explanations have changed the perception of risk posed by small tsunamis. A special mention has been made of the 1908 Messina-Reggio Calabria earthquake and tsunami, as well as the 2002 Stromboli event, induced by a flank collapse of the volcano, for their proximity with the surveyed school.

Particular attention has been given to best practices and success stories, such as the one of Tilly Smith, the English 10-yr old girl who saved her family and many other people on a beach in Thailand, having recognized the precursory signs of the impending 2004 Indonesian tsunami (specifically, the sea withdraw) after some school lessons she had followed a few days before leaving home for the vacation in the Indian Ocean [Owen, 2005; Gregg et al., 2006]. Other similar success stories of correct behaviors, such as the one of the Japanese Goryo Hamaguchi in 1835, were also useful to easily explain the importance of being aware of the risk.



Figure 3. Three shots of the Japanese footage showing in a tsunami simulator the power of a “small” tsunami wave.

After this lesson, which lasted about 30 minutes, we administered the same questionnaire as the first survey to the same students in each of the four classes. The results were very different from those of the first survey, as somehow expected. A much larger consciousness of the tsunami risk emerged on this occasion. In the next section, we discuss these results together with those of the previous survey and of the following one, which was obtained one year later.

2.2 The third survey

To complete the first methodological cycle and evaluate the effectiveness of the awareness-raising intervention for the students, one year after the lesson and the second survey, we went back to the school to carry out the third survey. Prof. LDF had previously prepared a schedule of meetings with the two fourth-year classes we had met the year before (thirds) and the fifth-year class. Unfortunately, the changeover from year to year did not allow us to reach the fifth upper class’ students, because they did finish their high school education the year of the first administration. The third administration of the questionnaire was indeed very quick.

A new upper fifth class was involved as a control group in this survey phase, having not participated in the previous administration or frontal lesson. The data collected in this new class were removed from the sample involved in the previous research phases. The response percentages for this “new” class, analyzed separately, are

very similar to the output percentages of the first survey phase, confirming the levels of perception and knowledge of tsunamis described above.

At the end of the questionnaire filling, more questions and curiosities emerged from the students, also solicited by our experiences in other schools and universities carried out in the past year. We realized that the students are very fascinated by storytelling, particularly if the stories have a scientific/realistic basis, as previously mentioned. These stimuli have activated a strong emotional recognition in them, evoked in the narrated stories and shown actions that hold their attention and facilitate learning.

Great attention was given by the students to the stories following the video footage, for example, the inappropriate behaviors captured in some videos of the Aegean tsunami of 30 October 2020, in which people are seen standing near the beach shooting videos or running towards the beach to get the best position for filming. These videos have more impact in explaining how to behave in the event of a tsunami, compared to just describing the same concept with words and pictures. As described above, one of the most effective videos is the one with the real tsunami simulator in Japan in which it is shown that an adult person can be dragged by the energy of a tsunami wave of only half a meter height but with the speed and the energy of a torrent in flood (Fig. 3).

It is worth remembering that during a tsunami alert in October 2018 [see Cirella et al., 2020; Papadopoulos et al., 2020; Amato et al., 2021], a mayor of a coastal city in Apulia (southern Italy) that was included in the Advisory alerted zone (i.e., expected runup of less than one meter), commented on a newspaper interview that he did not launch any alert to the citizens during the night of the potential tsunami because the waves expected on the coasts were of 1 meter (the Advisory alert level, see UNESCO, 2017), adding that in his municipality sea waves of 2-3 meters were common, and they do not cause any problem (From an interview to a local newspaper by the mayor of Otranto in 2018: <https://www.trnews.it/2018/10/26/rientrata-lallerta-tsunami-ma-saremmo-preparati/>).

Another video that attracted the students' attention is the one made by our Center with a webcam located on a beach of Samos island (in Kapirissia) when the tsunami triggered by the October 30, 2020 M7 earthquake [Dogan et al., 2020; Triantafyllou et al., 2021]. The video shows two sea withdraws followed by two waves of increasing height hitting a bathhouse a few minutes after the seismic event. The video had a strong emotional impact on the students. This is due to the relative proximity of the event to the Italian context (Greece and Italy are close both in space and in geology), and to the characteristics of the video in which the tsunami arrival time is very short and two people are risking their lives.

During the three phases, the Google tool used to run the survey allowed us to obtain a fast, though rough, response assessment from students who were curious to check and understand the results and asked several questions about it.

3. Results

Below we provide the results to the five target questions anticipated in the introduction. The results are provided in the same order to facilitate reading and interpretation.

- 1) In general, the second survey results show a rather different trend compared to the first one, with an increased knowledge and awareness by the students (Fig. 4). For question n. 1 (the possibility of a tsunami striking Italy): about 97% of the students declared that a tsunami is possible in Italy, whereas they were only 65% in the first survey. It is also worth noting the clear reduction of the undecided percentage (1% vs. 19% of the first test). In the third survey, the percentage decreased to 84% while only 5% think a tsunami could not hit Italy. Whereas the strong increase between the first and the second survey could be somehow expected (due to the live explanations), the gap between the first and the third survey, one year later, shows a slight decrease (95% to 84%), possibly suggesting the need for periodic recalls. This requires further evaluation of effectiveness over time, to survey the decay of knowledge following the peak levels in the second survey phase.
- 2) Regarding the question on the relative incidence of tsunamis in the Italian regions, considerable differences emerge in the three survey phases (Fig. 5). Significant differences are evident between the first and the second administration and a generally acceptable consistency between the second and the third administration. The regions where respondents express different opinions following the tsunami lesson include Sardinia and Apulia. In the first administration, 60% of the respondents considered Sardinia to be one of the regions most exposed to tsunamis. This value decreased to 16% in the second survey, following the speech by INGV researchers and the interactive lesson held in the classroom. In the third survey, it increased slightly to 24%. This value is acceptable

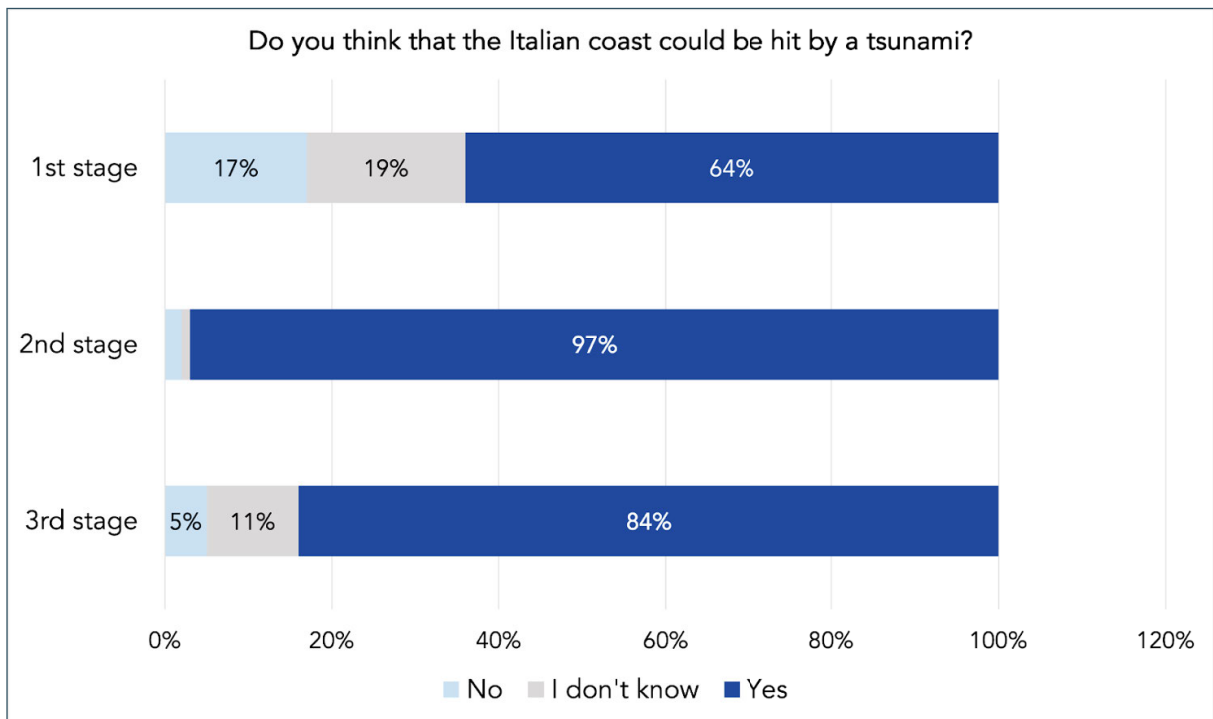


Figure 4. Percentage of responses to the question “Do you think that the Italian coast could be hit by a tsunami?” at stages 1, 2, 3.

compared to the lack of knowledge recorded in the first survey. Conversely, the respondents underestimate Sicily’s tsunami hazard in the first survey: only 24% of the students claimed that the Sicilian coast could be hit by a tsunami. The percentage almost doubles in the second survey and has a small decrease in the third survey (36%). Calabria has a similar trend to Sicily. In the first survey, 25% of respondents think it could be affected by a tsunami,

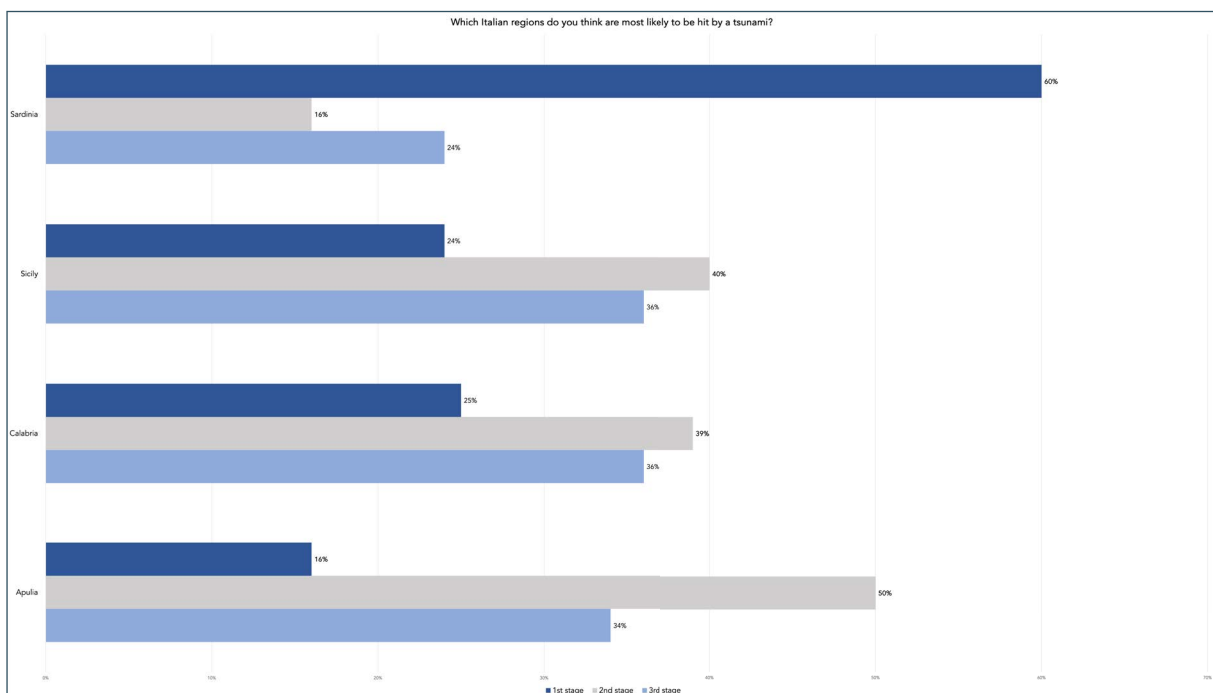


Figure 5. Percentage of responses to the question “Which Italian regions do you think are most likely to be hit by a tsunami?” for some regions, at stages 1, 2, 3, respectively.

in the second survey 39% and in the third survey 36%. Apulia is among the regions with the greatest percentage variation in the three survey phases. In the first phase, students underestimated the tsunami risk in the region, in fact only 16% of respondents indicated that Apulia could be affected by a tsunami. The percentage rises to 50% in the second survey and decreases to 34% in the third survey. Students, therefore, *tabula rasa* – in the first survey – seem to have a perception of tsunami risk in line with the national sample [Cugliari et al., 2022b], especially regarding the values associated with Apulia. Sardinia’s high percentage in the first survey may be due to its island location in the middle of the Mediterranean. Another possibility is that they got some misleading information from TV science shows in which it was suggested that a giant tsunami could have destroyed the “Nuraghe” civilization in the 2nd millennium BC. Less significant differences were found for the other regions.

3) The third question asked whether a 50 cm tsunami could drag an adult away (Fig. 6). In the first survey, 45% of the students responded positively while 32% of the respondents answered “don’t know”, and 23% were convinced that a 50 cm wave could not drag an adult away. After the lesson (which included viewing the video of the tsunami simulator in Japan and the Samos inundation of 2020), the response percentages changed. 86% of the students agree that a 50 cm tsunami can drag an adult person into the sea; only 10% remain in uncertainty limbo and only 4% suggest that this cannot happen. The third survey shows a decay of knowledge learned during the lesson. 63% express a positive opinion to the question (yes), the percentage of the uncertain also increases (25%) compared to the second survey, and those who do not believe that a 50 cm wave can drag an adult person into the sea rises to 12%.

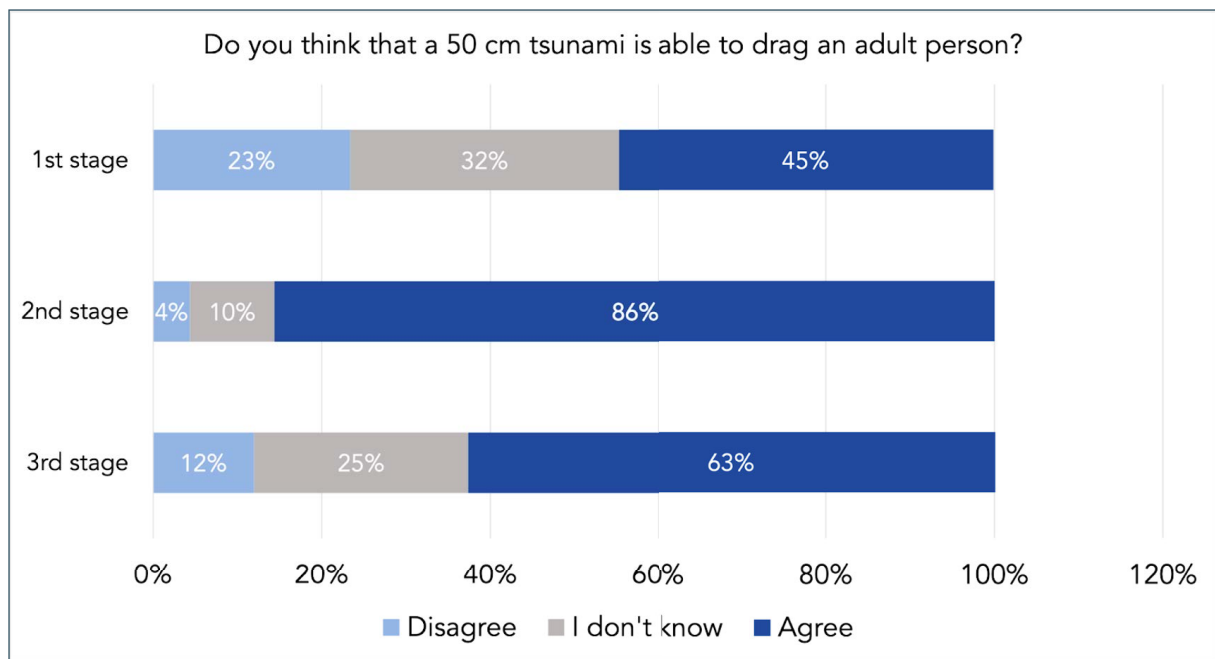


Figure 6. Percentage of responses to the question “Do you think that a 50 cm tsunami is able to drag an adult person?” at stages 1, 2, 3.

4) The fourth question we analyzed concerns the possibility of sending an alert message before the tsunami waves arrive (Fig. 7). In the first survey, only 17% of respondents answered that it is possible to be warned of the arrival of a tsunami before it hits the coast. Almost half of the students said that early warning is not possible. 34% remain neutral by answering ‘don’t know’. In the second survey, the scenario changes significantly, with almost half of the students saying that it is possible to warn the population before a tsunami impacts the coast. 32% claim that this cannot happen (not a low percentage since the questionnaire was administered after the lecture) and 20% place themselves on “don’t know”. Those who answered “yes” in the third administration were 41%, “no” decreased slightly (28%) while those who were uncertain increased to 32% of the total number of answers, almost the same as in the first survey.

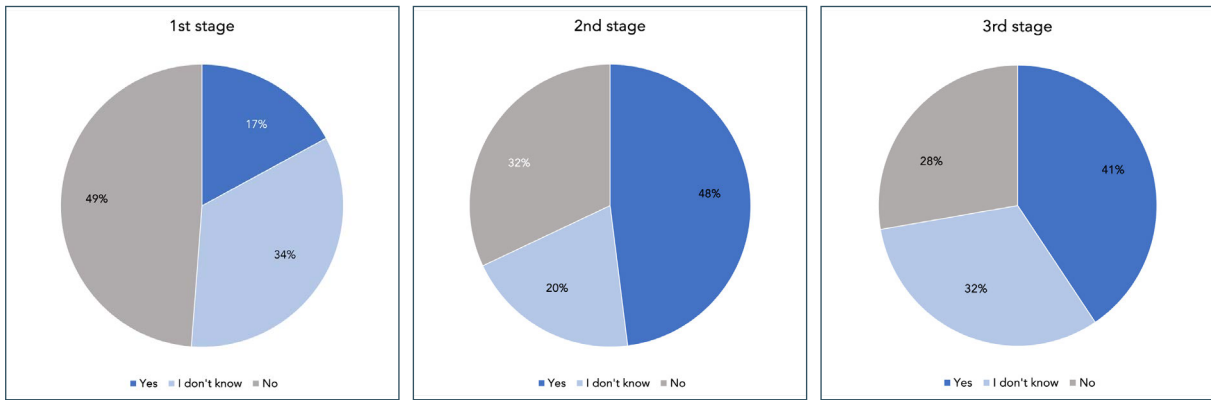


Figure 7. Percentage of responses to the question “In your opinion, is it possible to warn the Italian population of an imminent arrival of a tsunami?” at stages 1, 2, 3.

5) The fifth question that we analyzed here concerns the channels through which respondents would prefer to receive tsunami alerts (Fig. 8). The graph below shows the most significant outputs for this question, in which more than one answer was allowed. The response percentages for this question are aggregated for the three surveys. This was decided following the frequency percentage comparisons made between the three different administrations, which do not show any significant variations. Most of the respondents (57% of respondents) would prefer to be warned about the tsunami’s arrival through the sound of public sirens. On the other hand, 53% would prefer to be warned through TV messages, while only 49% of respondents would prefer to be warned through the Internet. These data suggest that teen-age students, although being digital natives, do not prefer to receive an intrusive warning via their mobile phones, but rather the warning should be disseminated by special devices or through mass communication channels that they can access. This latter aspect, however, needs further investigation.

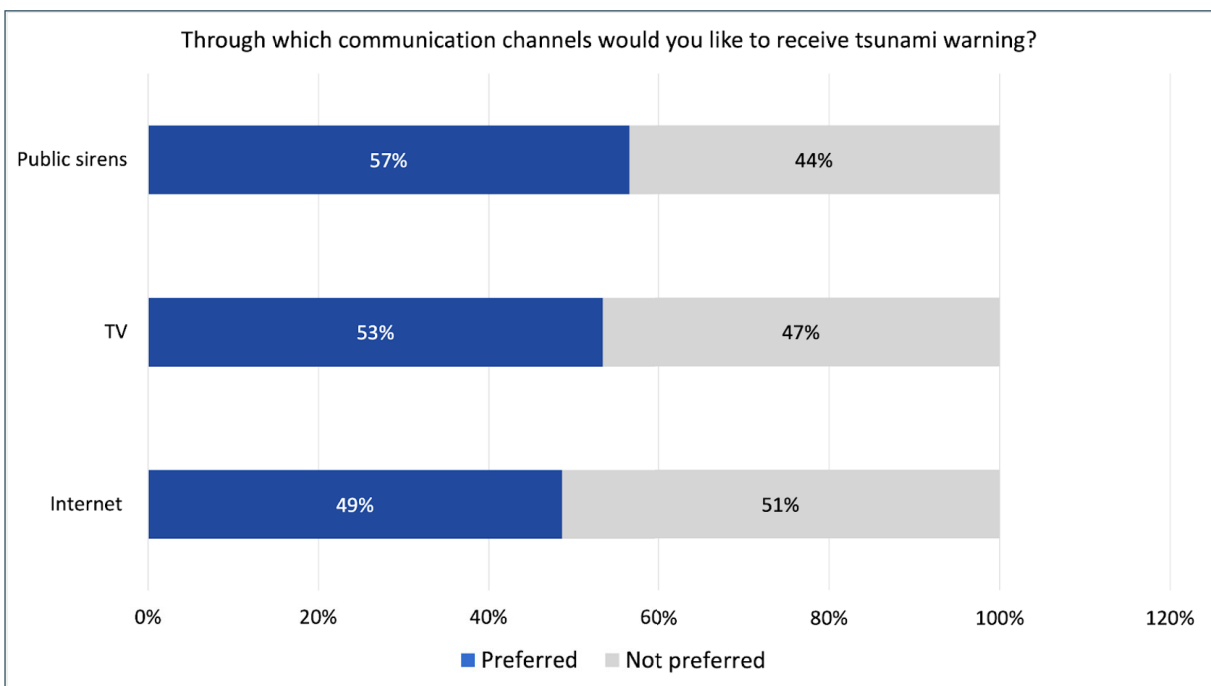


Figure 8. Percentage of responses to the question “Through which communication channels would you like to receive tsunami warning?”.

4. Discussion

We observed that administering the questionnaire to students in three stages, with an interactive, multimedia lesson in between, significantly changed the responses. The key result is a significant improvement in knowledge of the phenomenon and a more realistic risk awareness. The students' approach, when involved in the survey, was of great interest and surprise. The use of the online form to fill out the survey, by their mobile phones, was highly appreciated. Some students who were in "DAD" (Didattica A Distanza: Distance Learning, i.e. connected from home, due to the pandemic or adverse health conditions) also participated remotely.

The first research hypothesis (RH1), formulated after previous tsunami risk perception surveys [Cerase et al., 2019; Cugliari et al., 2022], assumed that the students have a low tsunami risk perception and poor phenomenon knowledge, as also suggested by the results of a national sample surveyed in the second of the cited studies. This hypothesis was only partially verified. In fact, in this case 60% of students believe that tsunamis are likely to occur in Italy, compared to the lower percentage of the Telepanel (19%). This result suggests a better knowledge of the phenomenon by the students compared to the average Italian population. This 60% percentage was detected in the first survey with the students, even before the lesson on tsunamis. Considering the different risk scores assigned to the various regions of Italy, a generally accurate perception emerges, with southern regions declared as more susceptible than their northern counterparts, which corresponds with the estimated hazard [Basili et al., 2021]. However, some biases seem to influence these perceptions, possibly resulting from media narratives about submarine volcanoes in the Tyrrhenian Sea. We also found that more than 80% of students believe that only tsunami waves higher than 1 meter can be dangerous to individuals, showing that the risk from small tsunamis is underestimated also among the young generations. This is in line with the percentage revealed in the national sample. This result is also confirmed by the direct exchange we had with the students after the first questionnaire was administered. The students, curious about the outcome of their answers – which clearly did not have an outcome as we explained to them that it wasn't an assessment – asked us whether it was correct to think that a small tsunami could drag an adult person along. To our response, they said that, in their imagination, "tsunamis were those waves seen in films and some documentaries of huge dimensions comparable to a building of several floors".

The second research hypothesis (RH2), based on the active learning theory [Johnson and Johnson, 2005] using multimedia support material extensively and open exchange of opinions to promote an interactive involvement of students in the learning process, was largely verified. In this context, students were involved in an inclusive and interactive lesson, characterized by an informal exchange of opinions and knowledge. During the lesson, various tools including images, videos, storytelling, and tsunami details, provided directly by the researchers in attendance were used. The aim of this approach was to stimulate students' interest and attention, encouraging them to actively explore the topic of tsunamis and gain a deeper understanding through direct interaction with the educational resources and experts in the field. The students expressed their positive assessment of the used approach and this was largely confirmed by the results of the second administration of the questionnaire. A significant increase was recorded in the number of responses supporting the possibility that Italy could be hit by a tsunami: from 65% in the first administration, this increased to 97% in the second administration. Such an increase highlights the effectiveness of the interactive and participatory approach adopted, which contributed to an increased awareness and understanding of tsunami risk among students.

The results for the third research hypothesis (RH3) showed that a significant amount of knowledge was retained over time, which is satisfactory. As shown above, the students involved in the longitudinal survey demonstrated good maintenance of acquired knowledge over time. The percentages found in the final phase of the research indicate good preservation of the information learnt during the course, despite a slight memory decay. It is particularly interesting to note that the students were able to recall the images presented in the videos even one year after watching them. This phenomenon underlines the effectiveness of multisensory communication, which involves both sight and hearing, together with the emotion generated during the learning process. This communicative approach is therefore extremely powerful in fostering a lasting memorization of information.

After the first administration, all four classes showed a high interest in the tsunami phenomenon and tsunami risks, with many questions on different topics e.g. "Can a tsunami travel around the world?", "How can a tsunami move so fast in the sea?", "Are there systems, such as reefs, that can limit a tsunami?", "how high did a tsunami wave reach?", "Does climate change affect tsunamis?".

All students were born after the 2004 Sumatra tsunami and they were children in 2011 at the time of the Great Japan Earthquake and Tsunami, so their knowledge comes from school or some articles and videos on TV or social

media. However, although Italy has a long history of tsunamis, there have been no notable events in recent years, so the media and public authorities' attention to tsunamis is very low. Moreover, even in school science curricula, there is a lack of specific information on tsunamis. The second survey, carried out about two months after the first visit, was useful to assess progress. We decided to use about half an hour of class time, and, in two classes, more than one hour of Prof. LDF's two-hour class time, to engage the students with many videos, prompting questions and discussions (some preliminary discussion had also been done during the first visit after the questionnaire had been administered).

During the second day's lecture, we further tested the importance of storytelling in the context of risk communication [Davidhizar and Lonser, 2003; Kromka and Goodboy, 2019]: from a psychological and learning perspective, students are attracted by storytelling and direct their attention to real-life experiences that evoke mental images and/or experiences in which they identify because they are aligned with their abilities. This happens particularly with stories in which the protagonists are peers of the interlocutors, in our case students, and evoke everyday situations in common life contexts. Storytelling provides multiple stimuli, eliciting most of the senses. On this occasion, we showed the students a screenshot of a magazine cover that dedicated its entire page to the news and a short, animated video on tsunami risk mitigation published in Indonesia with young people as protagonists. Narrative pathos also plays a key role. The experience communicated in this way triggers participatory listening, generating a learning-friendly environment.

Videos, especially, and images (mostly images showing tsunami effects that are easy to understand and possibly in contexts close to the observatories) are attractive tools generating curiosity, questions, and reflections in students. During these meeting days with students – and in other dissemination contexts to the general public (“Giornate dell'alfabetizzazione sismica” at INGV or events such as “The European Researchers' Night” etc.) – we have experienced that communication conveyed through short videos or, more generally, mediated by the screen and integrated by an expert's narration, provide broader and more accessible learning opportunities that are more easily memorized by the interlocutor who remains effectively impressed. We were able to verify how much the provided images persist in the interlocutor's memory in the different meetings with students, who, with emphasis, evoked the specific videos shown (e.g., video of the impact of the 2020 Samos tsunami on a building facing the sea) as in the meetings with the population. Those who were present at meetings where videos on tsunami impacts in the Mediterranean Sea or the simulation of a tsunami impact on an adult were shown, later recalled the specific details of the videos shown during the meeting. This emphasizes the now well-known need to use a mix of tools (traditional and innovative) to increase the potential for knowledge and learning.

The third survey engaged the students for about half an hour. They were already familiar with the structure of the questionnaire and remembered the previous two surveys. The survey outputs, however, show a general decrease in the “correct” responses. Some concepts were better assimilated by the respondents, also due to images, movies and videos shown during the lesson. Other concepts, more distant from the collective idea and worthy of appropriate knowledge, were forgotten. We can generally be satisfied with the approach. The respondents' level of perception increased and remained at a good level over time. To validate the effectiveness of the intervention, several administrations of the questionnaire should be planned on an annual basis over the years. To express satisfactory results, this methodology requires the availability of the same respondents for several repeated surveys over the years. We found the approach to be effective – within the limits of its application to a specific age range and with the possibility to repeat the survey every one or two years. We think that it would be useful to standardize it in some way, so that it can be easily reproduced and used by non-experts of the specific field, such as Science teachers (with evaluation *in itinere*).

A brief remark, which needs to be further explored, concerns the opinions of the interviewees expressed in the open-ended questions. In fact, regarding the open questions that were added to the questionnaire to replace section 5, almost all participants (over 94%) said they would like to receive more information about this type of risk. To the first open-ended question: “*How would you prefer to be informed about natural hazards and prevention?*”, most of the answers converge on social media, but also on school and meetings with competent people. In fact, a quick and unstructured analysis of the social media most frequently used by young people in the age group of the interviewees (TikTok and Instagram) shows that concerning tsunamis, especially on TikTok there is no official page of a scientific institution, civil protection organization or influencer dealing with this topic in the language of the platform, and with scientifically correct information. On Instagram there are a few dedicated channels that often provide fragmentary information that in any case does not speak the language of young people.

Regarding the open-ended long question: “*What do you think is the best way to raise the population's awareness about knowledge and prevention of natural hazards?*”, the interviewees focus their attention on TV as a media-mainstream

that maintains its dissemination significance. E.g. some suggest: “*Bringing TV programmes during peak hours and on the main TV channels can be an efficient medium, I find the programming currently present insufficient.*” or those who “*Talk about it in TV programmes, organize events on the territory*” and those who summarize with: “*School and TV*”.

Another interesting aspect emerging from the data analysis concerns the channels through which respondents would prefer to receive a tsunami warning. Considering the age range, the answers collected seem to contradict the widespread use of smartphones by young people [Zhitomirsky-Geffet and Blau, 2016; Shorey et al., 2024]. A similar result was found in the national CATI survey covering, to date, 8 Italian regions [Cerese et al., 2019; Cugliari et al., 2022], and was considered a bias in the use of the medium. It appears contradictory to suggest TV as a preferred channel for receiving an alert. This is especially true considering that we received such a response from teenagers, who are digital natives and rely on their smartphones as one of their main means of communication with the world [Bentley et al., 2015; Ricoy et al., 2022]. We could hypothesize that this result is a consequence of the cultural background in which TV is still a central part of domestic life. We could also suppose that students think about the digital divide of older people, imagining that receiving an alert via TV could be more effective and understood by their parents and grandparents. However, this would not be a new result and could be related to information overload factors which respondents are daily exposed to [Bawden and Robinson, 2020; Priporas et al., 2024]. This aspect, in any case, goes beyond the scope of this study and needs further investigation.

It is also interesting to compare the perception of risk detected in the Telepanel survey with that of the Spallanzani high school’s students. Both samples consist of citizens who, although not residing in coastal areas, may be potential tourists who use to spend their vacations in coastal destinations in Italy or abroad. According to the analysis, students display a better understanding of the risk of a tsunami as compared to the sample of Telepanel respondents, indicating that age could be a factor in this. International studies [Kelman et al., 2008; Rittichainuwat, 2013; Arce et al., 2017; Takabatake et al., 2017; Hall et al., 2019; Hall et al., 2023] emphasize the importance of implementing tsunami risk mitigation policies aimed at tourists who, even for short periods, visit coastal areas at tsunami risk.

5. Conclusions

In conclusion, we can say that the methodology used to increase knowledge of tsunami risk to the target students is effective. Meeting the students in person, in the three different phases, was crucial. Especially in the first research phase, post-COVID-19, students showed a good interest in welcoming researchers to introduce a new topic to them through a dynamic, interactive lesson supported by images and videos. Regarding the effectiveness of the longitudinal study, it is crucial to compare the first survey with the second and third administrations.

The second survey shows a considerable change in trend compared to the initial one. Indeed, greater knowledge and awareness emerged among the students. For example, about the possibility of a tsunami occurring in Italy (question 1), there was a huge positive increase between the first and second survey and, parallel to it, there was a significant decrease in the percentage of undecided, from 19% to 1%.

In the third survey, a slight decrease occurred for the same question, with only 5% indicating that a tsunami could not hit Italy. While the substantial increase between the first and second surveys could be expected due to live explanations, the slight decrease observed between the first and third surveys, conducted one year apart, suggests the need for periodic reinforcement.

In terms of knowledge preservation, responses to the question on the impact of a 50 cm tsunami on an adult significantly shifted after the lesson. Initially, a small percentage of students believed that a 50 cm tsunami could drag an adult into the sea; this percentage doubled after the lesson, indicating a substantial increase in awareness. However, the knowledge decay was greater in the third survey, with a decrease in affirmative responses and an increase in uncertainty compared to the second survey.

Regarding early warning systems, perceptions changed significantly between the first and second surveys, with a significant increase in the belief that it is possible to warn the population before a tsunami hits. Preferences on receiving tsunami warnings also varied, with most respondents expressing a preference for public sirens and television messages over digital notifications. Probably this could be associated with the intrusiveness that digital marketing and the invasive advertising campaigns of various multinationals have acquired in recent years, so people have a tendency not to respond to or accept messages from unknown parties. Another explanation could be associated with the desire to safeguard their privacy and the exclusivity of their smartphones. A further interpretation

could derive from the respondents' lack of familiarity with how a telephone notification alert system works and their worry of not understanding an alert message or confusing it with the multitude of daily notifications that they receive on their smartphones. This suggests a preference for non-intrusive warning methods among adolescent students. However, this is not the purpose of the survey, but this is valuable information that could be further investigated, possibly using qualitative methods, to improve or adapt the alert channels. It should be added that, at the survey time, the testing of the public IT-Alert system by the national Civil Protection Department had not yet been carried out (in Latium the testing was done in September 2023), so, as previously mentioned, the students had no knowledge and experience of receiving an alert via telephone. On the other hand, it must be noted that in Italy, during the COVID-19 pandemics the attempt of using a contact tracing system (specifically the app IMMUNI) based on smartphones was not successful, due to several reasons [Guazzini et al., 2021], and this could have had a negative effect on the use of smartphones for institutional messaging.

In conclusion, we can generally be satisfied with the proposed approach. The respondents' tsunami risk perception increased and remained at a good level over time. To validate the effectiveness of the intervention, several administrations of the questionnaire should be planned on an annual or biennial basis over the years. To do so, we suggest a combination of: a) questionnaire 1; b) a recorded lesson with video footage; c) questionnaire 2, to be issued by teachers without direct intervention by scientists. This could lead to a widespread assessment of tsunami risk perception in the Italian youth population, and hopefully to greater knowledge not only of the teachers and of the students but also of their families.

Data availability statement. Data can be downloaded at: <https://forms.gle/Zb3w4aTJsgTB9cTz9>

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APPENDIX



QR code as access point to the tsunami risk perception questionnaire.

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