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Received: 02/05/2026
Revised: 16/06/2026
Accepted: 01/08/2026
Published: 05/08/2026

Editor:
Dr Alexandros Bartzokas-Tsiompras

DOI: 10.48088/ejg.a.mor.17.1.284.299
ISSN: 1792-1341
E-ISSN: 2410-7433

Research Article

School Students' Perceptions of Natural-Hazard Risk in Mediterranean Spain: Education, Prevention, and Climate Change

Álvaro-Francisco Morote [1]✉, Alberto Alfonso-Torreño [2], Jorge Olcina [3], Brenda Tévar [4], Ángela Zaragoza [5] & Danielle H. Heinrichs [6]

[1] Department of Experimental and Social Sciences Education, University of Valencia, Spain
[2] Department of Didactics of Social Sciences, Language and Literature, University of Extremadura, Spain
[3] Department of Regional Geographical Analysis, and Physical Geography, University of Alicante, Spain
[4] CEIP l'Albereda, Spain
[5] IES Dos Mares, Spain
[6] School of Education and Professional Studies, Griffith University, Australia

✉ Correspondence: alvaro.morote@uv.es

Abstract: Mediterranean schools operate in territories increasingly exposed to floods, heat, drought, wildfire, and other natural hazards, yet students' risk literacy and preparedness remain uneven. This study compares the perceptions of Primary Education, Secondary Education, and Baccalaureate students regarding information sources, preventive education, textbook coverage, and the expected influence of climate change and human activity on future hazards. A non-experimental, pooled cross-sectional questionnaire survey was conducted with 985 students from the Valencian Community and the Region of Murcia, Spain, recruited through non-probability convenience sampling. The analysed Likert-type item blocks were summarised descriptively and compared across educational stages using the Kruskal-Wallis H test and epsilon-squared effect sizes. Primary Education students reported stronger reliance on family and school and consistently higher exposure to preventive instruction, whereas social media became the highest-rated information source in Baccalaureate. Older students generally attributed greater future importance to climate-sensitive hazards and stronger effects to climate change and human activity. However, most stage effects were negligible or small; moderate effects were limited to selected preventive-education outcomes and the perceived climate-change influence on drought. The findings support a progressive, stage-sensitive approach to curricular integration that combines local hazard knowledge, action protocols, critical evaluation of digital information, and teacher pedagogical content knowledge. Because the sample was non-random and regionally bounded, the results should be interpreted as evidence about the participating students rather than population estimates for Spain.

Keywords: natural hazards; risk perception; risk literacy; preventive education; geography education; climate change

Highlights:

- Primary students reported the strongest school- and family-based preventive education
- Social media and concern about climate-sensitive hazards increased towards Baccalaureate
- A coherent curriculum progression should connect hazard knowledge, source evaluation, and protective action

1. Introduction

The Mediterranean basin is exposed to interacting atmospheric, hydrological, geophysical, and ecological hazards, and climate change is amplifying several dimensions of heat, drought, wildfire, and heavy-precipitation risk (Intergovernmental Panel on Climate Change [IPCC], 2022; Khodayar et al., 2025; Pérez-Morales et al., 2025; Romero & Camarasa, 2025). The 29 October 2024 cut-off-low episode in Valencia provided a particularly severe regional example: catastrophic flooding caused extensive loss of life and the destruction of public and private assets estimated at more than EUR 17 billion (*Instituto Valenciano de Investigaciones Económicas* [IVIE], 2025; Pérez-Cueva et al., 2025). Such events make the educational treatment of hazards, vulnerability, preparedness, and protective action an immediate question for schools in Mediterranean Spain.

Children and adolescents are not only potential disaster victims; they are also learners, household communicators, and future decision-makers, and disaster exposure can have substantial short- and long-term consequences for their wellbeing (Squires et al., 2023). International research nevertheless indicates that students' risk perception, preparedness, and knowledge of appropriate responses are often partial, uneven, or weakly connected to the hazards present in their own territories (Almeida et al., 2020; Antronico et al., 2023; Bandecchi et al., 2020; Martins et al., 2023; Martins & Nunes, 2026; Pal et al., 2023; Papagiannaki et al., 2024; Yildiz et al., 2021). A recurring problem is the gap between recognising that a phenomenon is dangerous and knowing what to do before, during, and after an event. This gap is educationally significant because awareness without procedural competence does not, by itself, produce resilience.

The information environment further complicates this task. School and family remain important sources of knowledge, but adolescents increasingly encounter climate and hazard narratives through social media. Digital platforms can provide rapid access to warnings and local evidence, yet they also circulate decontextualised images, catastrophic framings, and misinformation (Daume, 2024; Lutzke et al., 2019). Risk education therefore needs to address both substantive geographical knowledge and the capacity to evaluate sources, evidence, uncertainty, and spatial context.

Spain's current competence-based curriculum gives formal visibility to climate change, natural hazards, prevention, civil protection, and territorial resilience. However, curricular presence does not guarantee systematic implementation, continuity across stages, or an explicit progression from conceptual understanding to protective action. Research on Spanish teaching materials and student conceptions has similarly identified fragmented coverage and a frequent emphasis on causes and descriptions rather than prevention, vulnerability, and response protocols (Alfonso-Torreño et al., 2026; Morote et al., 2026). Although many studies have explored students' views on natural hazards, disaster preparedness, and climate change, few have compared these issues across Primary, Secondary, and Baccalaureate education. This is particularly important in Mediterranean Spain, where increasingly frequent floods, droughts, and wildfires highlight the need for effective disaster-risk education. Comparing educational stages helps identify how students' knowledge, information sources, and understanding of risk develop over time, while revealing possible gaps in the progression of risk literacy. The general objective of this study is to analyse how students in Primary Education, Secondary Education, and Baccalaureate perceive the education they receive about natural hazards, the prevention measures addressed at school, and the likely future influence of climate change and human activity on these phenomena. Two specific objectives guide the analysis: SO1, to examine students' main information sources, perceived preventive education, and perceived textbook coverage; and SO2, to analyse their perceptions of climate-change influence, human influence, and the future importance of different hazards.

- H1. Information sources, perceived preventive education, and perceived textbook coverage differ across educational stages. Primary Education students are expected to report greater reliance on school and family and more preventive instruction, whereas social media is expected to be more prominent in Secondary Education and Baccalaureate.
- H2. Attributions of future hazard intensification to climate change and human activity, and the importance assigned to climate-sensitive hazards in the future, increase with educational stage. The expectation is strongest for heat and cold waves, torrential rain and flooding, droughts, and forest fires rather than for geophysical hazards.

2. Literature Review and Conceptual Framework

2.1. Terminology and international policy context

Terminology is used consistently throughout this article. A natural hazard is a potentially damaging physical process or event; disaster risk emerges from the interaction of hazards with exposure, vulnerability, and coping capacity. Risk perception refers to students' subjective judgements about the seriousness, causes, and future relevance of hazards. Preventive education denotes planned teaching that develops anticipation, preparedness, and protective action before an emergency. Risk literacy is the broader capacity to interpret hazard and risk information, assess evidence and uncertainty, and make informed decisions. Curricular integration refers to the deliberate and progressive embedding of these elements across subjects, educational stages, learning activities, and assessment.

These concepts align with the Sendai Framework for Disaster Risk Reduction 2015-2030, which emphasises understanding risk, strengthening governance, investing in resilience, and improving preparedness (United Nations Office for Disaster Risk Reduction [UNDRR], 2015). They also connect directly with Sustainable Development Goal (SDG) Target 4.7 on education for sustainable development, Target 11.b on integrated resilience and disaster-risk plans, and Target 13.3 on climate education, awareness, capacity, impact reduction, and early warning (United Nations [UN], 2015). For schools, implementation therefore requires more than isolated content: it requires coherent learning progressions, safe-school planning, teacher preparation, and opportunities to apply knowledge to local situations.

Preventive education is especially effective when it joins disciplinary explanation with action competence. Students need to understand why hazards occur, where exposure and vulnerability are concentrated, how warnings are produced, and which protective actions are appropriate. Studies of flood and climate education show that local cases, maps, simulations, drills, and problem-based tasks can strengthen engagement and willingness to act, although outcomes depend on the quality of instruction and its integration into the curriculum (Kolenatý et al., 2022; Masocha et al., 2025; Putra et al., 2022; Roca et al., 2025).

2.2. Geography education, teacher knowledge, and information environments

Geography is particularly well placed to support risk literacy because it connects physical processes, spatial patterns, human vulnerability, territorial planning, and public decision-making. Contemporary geography-education research emphasises that teachers do not simply transmit a prescribed curriculum; they make curricular decisions about which geographical knowledge, cases, representations, and enquiries are educationally powerful (He et al., 2024; Mitchell et al., 2022). This places pedagogical content knowledge at the centre of effective risk education, including the ability to anticipate misconceptions, select locally meaningful examples, interpret maps and data, and design tasks that move from explanation to informed action (Favier et al., 2021; Smit et al., 2023).

Recent work in the European Journal of Geography reinforces this disciplinary perspective. Mar-Beguería et al. (2026) show that teachers' conceptions shape how geographical thinking is mobilised in climate-change education. Lämmer and Ohl (2026) demonstrate that even primary pupils need support to evaluate climate-related misinformation, while Robakiewicz et al. (2026) identify weaknesses in scientific-data awareness among future geography educators. Together, these studies suggest that preventive education should integrate geographical reasoning, media and data literacy, and explicit discussion of evidence quality rather than treating hazards as a catalogue of events. Related studies have also reported gaps in climate-change and hazard preparation among students and future teachers (Alfonso-Torreño et al., 2026; Morote & Hernández, 2024).

The distinction between hazard types is also conceptually important. Climate change can influence the frequency, intensity, duration, or spatial distribution of many atmospheric and hydrological hazards, but it does not cause tectonic earthquakes or volcanic eruptions. Students who attribute every disaster to climate change may therefore display concern without disciplinary discrimination. Conversely, low concern may reflect either weak knowledge or an accurate judgement that a particular hazard is not climate-driven. Analyses must consequently consider both the direction and the substantive plausibility of students' responses.

2.3. Curricular context in Spain and the study regions

The national curriculum established under Organic Law 3/2020 (LOMLOE) frames education for sustainable development, climate action, and responsible citizenship as cross-curricular priorities (Government of Spain, 2020). During the study's fieldwork period, the minimum curricula were specified by Royal Decrees 157/2022 for Primary Education, 217/2022 for compulsory Secondary Education, and 243/2022 for Baccalaureate (Government of Spain, 2022a, 2022b, 2022c), and implemented regionally through the corresponding decrees in the Valencian Community and the Region of Murcia (*Generalitat Valenciana*, 2022a, 2022b, 2022c; Region of Murcia, 2022a, 2022b, 2022c).

At Primary level, the prescribed curriculum introduces climate-change causes and consequences, mitigation and adaptation, the SDGs, civil protection, and citizen collaboration in disasters. Its treatment is broad and cross-curricular, which creates opportunities for local, family-linked, and action-oriented learning but may also lead to uneven depth between schools. In compulsory Secondary Education, hazards are more explicitly connected to atmospheric processes, climatic risks and catastrophes, vulnerability, prevention, resilience, geological processes, and risk maps. The formal curriculum therefore supports more analytical treatment and stronger links between physical and human geography, although converting complex environmental content into meaningful and applied learning remains a recognised didactic challenge (Ajón, 2016).

In Baccalaureate, hazard education can become more specialised. Relevant subjects address relationships between natural processes and human activity, prediction and prevention, territorial planning, data evaluation, and the critical assessment of scientific claims. However, exposure depends more strongly on the student's pathway and subject choices. Formal curricular sophistication may therefore increase while the continuity of preventive education becomes selective. This distinction between intended curriculum and experienced curriculum is central to interpreting stage differences: the present study records students' perceptions of what they have encountered, not whether teachers or schools complied with every curricular prescription.

3. Materials and Methods

3.1. Research design

The study used a non-experimental, pooled cross-sectional, comparative survey design (Pérez-Castaños & García-Santamaría, 2023). Data were collected during the first semester of the 2024-2025 and 2025-2026 academic years and analysed as one pooled dataset. The design did not include longitudinal follow-up or a comparison between collection years. The broader questionnaire contained quantitative and qualitative questions, but the analyses reported here concern the selected Likert-type item blocks described below.

3.2. Context, participants, and sampling

Participants were 985 students enrolled in schools in eastern and south-eastern Mediterranean Spain, specifically the Valencian Community and the Region of Murcia. The sample included 339 students in the third cycle of Primary Education (Grades 5 and 6), 473 in Secondary Education, and 173 in Baccalaureate (upper-secondary education). The mean age was 13.4 years (Table 1). The gender distribution was 519 male students (52.7%) and 466 female students (47.3%).

Table 1. Sociodemographic characteristics of the participants

Educational stage	n	%	Male, n (%)	Female, n (%)	Mean age
Primary Education (Grades 5-6)	339	34.4	186 (54.9)	153 (45.1)	10.7
Secondary Education	473	48.0	240 (50.7)	233 (49.3)	14.1
Baccalaureate	173	17.6	93 (53.8)	80 (46.2)	16.7
Total	985	100.0	519 (52.7)	466 (47.3)	13.4

Note: Percentages in the male and female columns are within-stage percentages. The Primary male percentage has been corrected from 34.9% to 54.9%.

It should be noted that fieldwork did not take place in the area most severely affected by the 29 October 2024 floods (the southern districts of the city of Valencia). Owing to the extent of the damage—school closures, temporary classrooms, and significant disruptions to educational activity—conducting research in these schools was neither feasible nor ethically appropriate during the first semester of the 2024–2025 academic year. Access to these centres remains a methodological challenge to be addressed in future research cycles. Importantly, the participants in this study were drawn from a diverse set of schools across the Valencian Community and the Region of Murcia, rather than exclusively from the zone closest to the 2024 floods. This broader sampling strategy ensures that the dataset reflects a wider regional context and is not limited to the immediate post-disaster conditions of the most affected localities.

Recruitment used non-probability convenience sampling (Wellington, 2015). Schools and students were accessed through the researchers' existing professional networks and their availability during the fieldwork period. No sampling frame, random school selection, random student selection, or known inclusion probability was used. Consequently, the sample cannot be considered statistically representative of all students in the two regions, Mediterranean Spain, or Spain as a whole. The available sampling records did not permit a reliable reconstruction of the exact number and distribution of participating schools. This lack of school-level sampling information is acknowledged as a limitation.

3.3. Research instrument

The instrument was the 17-question questionnaire Natural Risks: Teaching and Social Representation developed by Morote (2025). For conceptual consistency, the present article uses the term natural hazards when discussing the physical phenomena and reserves risk for their interaction with exposure, vulnerability, and capacity. Six item blocks were selected because they map directly onto SO1 and SO2. For reporting clarity, the item descriptions presented in Table 2 are paraphrased in English. All analysed items were measured using five-point Likert-type response scales; however, the response anchors varied according to the construct being assessed (e.g., extent of information received, educational coverage, or level of agreement), as indicated in Table 2.The overall questionnaire demonstrated excellent internal consistency (Cronbach's $\alpha = 0.923$). Reliability was also high for Blocks 8 ($\alpha = 0.892$), 9 ($\alpha = 0.898$), 14 ($\alpha = 0.852$), 15 ($\alpha = 0.866$), and 16 ($\alpha = 0.889$). Block 5 showed a lower but acceptable level of internal consistency ($\alpha = 0.675$), which is expected because its items assess different sources of information rather than a single latent construct and were therefore not intended to form a unidimensional scale. Overall, these results indicate satisfactory reliability for the questionnaire and its analysed domains (Raykov & Marcoulides, 2017).

Table 2. Analysed questionnaire item blocks

Item	Domain	Reported content	Reponse scale	Objective
5	Information sources	Extent to which information is received from family/friends, social media or the Internet, television, newspapers, radio, school, and NGOs	1 = None – 5 = A great deal	SO1
8	Preventive education	Extent to which school has explained prevention measures for each hazard	1 = Not at all – 5 = To a great extent	SO1
9	Textbook coverage	Extent to which Geography or Social Sciences textbooks address each hazard	1 = Not at all – 5 = To a great extent	SO1
14	Climate-change influence	Extent to which climate change is expected to worsen each hazard	1 = Strongly disagree – 5 = Strongly agree	SO2
15	Human influence	Extent to which human activity is expected to worsen each hazard	1 = Strongly disagree – 5 = Strongly agree	SO2
16	Future hazard salience	Extent to which each hazard should be taken into account in the future	1 = Strongly disagree – 5 = Strongly agree	SO2

Note: Items 8, 9, 14, 15, and 16 rated the same hazards: hail; heat and cold waves; torrential rain and flooding; earthquakes; snowstorms; volcanoes; windstorms; droughts; and forest fires. Responses ranged from 1 (strongly disagree) to 5 (strongly agree).

3.4. Procedure, ethics, and response-quality safeguards

The questionnaire was administered in person on paper and required approximately 15 minutes during the first semester of the 2024-2025 and 2025-2026 academic years (December). The questionnaire was administered collectively during regular class time under the supervision of both the research team and classroom teachers. Participants were encouraged to ask for clarification whenever necessary, and the administration conditions were intended to promote attentive completion of the questionnaire. The same instrument, response scale, paper mode, and approximate completion time were used throughout the fieldwork. These procedural consistencies reduce administration-related variability, but they cannot eliminate response biases.

https://doi.org/10.48088/ejg.a.mor.17.1.284.299

Families received prior written information about the study's purpose and characteristics, and the consent procedure required by the participating institutions was followed. Students received an age-appropriate explanation of the research and participation was treated as voluntary. Questionnaires were anonymous: no names or other direct identifiers were included in the analytical dataset, confidentiality was maintained, and results are reported only in aggregate. Processing complied with Organic Law 3/2018 on personal-data protection and digital rights (Government of Spain, 2018). Under the institutional rules applicable at the authors' university, anonymous non-health opinion and perception questionnaires do not require review by the health-research ethics committee; therefore, no formal approval number was issued.

Potential response biases were addressed primarily through anonymous administration and a common instrument and response format. Nonetheless, the survey depends on self-report and may be affected by recall error, social desirability, acquiescence, age-related differences in item comprehension, current media exposure, and eco-anxiety. These residual risks are made explicit in Section 7 rather than being treated as fully controlled.

3.5. Data analysis

Analyses were performed using SPSS version 29 and STATISTICA version 8. Descriptive means were used to identify broad response patterns. Because the grouping variable had three educational stages and the item responses were ordinal, stage distributions were compared using the Kruskal-Wallis H test. The test indicates whether at least one group distribution differs; it does not identify which pairs differ. No post-hoc pairwise tests were available, so the discussion refers to observed mean-rank patterns and avoids unsupported pairwise significance claims.

Effect size was calculated as epsilon squared, epsilon-squared = max[0, (H - k + 1)/(N - k)], where k is the number of groups and N is the valid item-specific sample size. Values below 0.01 were treated as negligible, 0.01-0.059 as small, 0.06-0.139 as moderate, and 0.14 or above as large (Tomczak & Tomczak, 2014). Exact p values are reported to three decimals when p >= 0.001; smaller values are reported as p < 0.001. The statistics describe separation within the observed convenience sample. In the absence of probability sampling, they should not be interpreted as design-based estimates of population uncertainty or as evidence that the sample represents all Spanish students (Hirschauer et al., 2020).

4. Results

The main text focuses on overarching patterns and practical magnitude. Detailed mean ranks, H statistics, p values, and effect sizes are consolidated in Appendix A.

4.1. Information sources, preventive education, and textbook coverage

SO1 examined information sources, preventive education, and textbook coverage. For information sources, Primary Education students gave their highest ratings to family/friends (mean 3.5) and school (mean 3.4), whereas social media was the highest-rated source in Baccalaureate (mean 4.0). The Kruskal-Wallis results showed stage differences for family/friends, social media, and school, but not for television. Effect sizes were small for the significant outcomes (epsilon-squared = 0.016-0.035), indicating that educational stage accounted for only a limited share of the observed variability (Appendix Table A1).

Perceived preventive education was generally low to moderate and was consistently strongest in Primary Education. Primary students had the highest mean rank for every hazard, while Secondary Education generally had the lowest. Stage differences were detected for all nine hazards, with effects ranging from small to moderate. The largest effects concerned hail, heat and cold waves, snowstorms, volcanoes, and windstorms. These findings describe the students' reported exposure to prevention content; they do not demonstrate that Primary schools objectively implemented more or better training (Appendix Table A2).

Textbook coverage was perceived as moderate to low overall. Baccalaureate students reported the highest mean ranks for most hazards, while Secondary Education tended to have the lowest. Stage differences were detected for all hazards except droughts. Most effects were small, and the forest-fire effect was statistically detectable but negligible. The pattern is therefore not a simple decline across stages: reported preventive instruction was highest in Primary Education, whereas reported textbook coverage often increased again in Baccalaureate. Table 3 summarises the main findings; detailed results are provided in Appendix Tables A1-A3..

Table 3. Summary of results for information sources and educational exposure (SO1)

Domain	Principal stage pattern	Kruskal-Wallis result	Practical magnitude
Information sources (Item 5)	Primary: family/friends and school rated most highly. Baccalaureate: social media rated most highly.	Differences for family/friends, social media, and school (all p < 0.001); no difference for television (p = 0.133).	Significant effects small (epsilon-squared = 0.016-0.035).
Preventive education (Item 8)	Primary had the highest mean rank for all nine hazards; Secondary generally had the lowest.	Differences for every hazard (all p < 0.001).	Small-to-moderate effects (epsilon-squared = 0.046-0.088).
Textbook coverage (Item 9)	Baccalaureate had the highest mean rank for most hazards; Secondary tended to have the lowest.	Differences for eight hazards; no difference for droughts (p = 0.057).	Effects negligible-to-small (epsilon-squared = 0.004-0.055).

Note: Full item-level statistics are provided in Appendix Tables A1-A3. Kruskal-Wallis tests identify an overall stage difference but not specific significant pairs.

4.2. Climate change, human activity, and future hazard salience

SO2 examined perceived climate-change influence, human influence, and future hazard salience. Climate-change attribution was strongest for hazards that are plausibly climate-sensitive: the highest overall means were recorded for heat and cold waves (3.9), droughts (3.6), forest fires (3.6), and torrential rain and flooding (3.5). Baccalaureate students had higher mean ranks for most of these hazards. The largest stage effect concerned droughts (epsilon-squared = 0.090, moderate). By contrast, volcanoes showed no stage difference, and the statistically detectable difference for earthquakes was negligible. This pattern suggests some disciplinary discrimination rather than an indiscriminate attribution of all hazards to climate change. Nevertheless, because the survey did not assess students' underlying reasoning, the same pattern could also reflect lower salience or familiarity of geophysical hazards (Appendix Table A4).

For human influence, the highest overall means concerned forest fires (3.7), droughts (3.5), heat and cold waves (3.4), and torrential rain and flooding (3.0). Baccalaureate students again tended to report higher ratings, but stage differences were absent for snowstorms, volcanoes, and windstorms. All detected effects were negligible or small. Students therefore associated human activity more strongly with some climate-sensitive and land-management-related hazards than with geophysical hazards, but the educational-stage gradient was not uniform (Appendix Table A5).

Future concern was highest for forest fires (3.9), heat and cold waves (3.8), torrential rain and flooding (3.8), and droughts (3.7). Baccalaureate students generally expressed the greatest concern, particularly for droughts, forest fires, and torrential rain. No stage differences were detected for snowstorms or windstorms, and all effect sizes were negligible or small. Table 4 summarises SO2; detailed results are provided in Appendix Tables A4-A6.

Table 4. Summary of results for climate change, human activity, and future salience (SO2)

Domain	Principal stage pattern	Kruskal-Wallis result	Practical magnitude
Climate-change influence (Item 14)	Baccalaureate generally highest for climate-sensitive hazards; volcanoes showed no stage difference.	Differences for eight hazards; volcanoes p = 0.210.	Mostly negligible/small; droughts moderate (epsilon-squared = 0.090).
Human influence (Item 15)	Baccalaureate tended to rate human influence more strongly for hail, heat/cold, torrential rain, droughts, and forest fires.	No differences for snowstorms, volcanoes, or windstorms.	All effects negligible/small (epsilon-squared = 0.000-0.031).
Future hazard salience (Item 16)	Concern generally increased by stage for climate-sensitive hazards; volcanoes were an exception to the linear pattern.	No differences for snowstorms or windstorms.	All effects negligible/small (epsilon-squared = 0.003-0.049).

Note: Full item-level statistics are provided in Appendix Tables A4-A6. Interpretations distinguish climate-sensitive hazards from geophysical hazards.

5. Discussion

The findings show that students' understanding of risk changes across educational stages, but not in a steady or uniform way. Different aspects of risk literacy develop at different rates, revealing gaps between stages that should be addressed through curriculum improvement. H1 is partially supported. Primary Education students reported greater reliance on school and family and more preventive instruction, while social media was most prominent in Baccalaureate. However, television did not vary by stage, and textbook coverage did not follow the same pattern as preventive education. Baccalaureate students often reported greater textbook exposure, suggesting that content coverage and action-oriented preparation are distinct dimensions of the experienced curriculum.

The shift towards social media is educationally important even though its effect size was small. Social media can connect students with warnings, eyewitness evidence, and public debate, but it can also amplify emotionally salient or misleading claims (Daume, 2024). Risk literacy should therefore include source triangulation, the distinction between hazard and disaster, interpretation of uncertainty, and attention to the spatial and temporal context of images and statistics. This implication is consistent with research showing that brief critical-thinking interventions can reduce susceptibility to climate misinformation (Lutzke et al., 2019) and with recent geography-education work on fake-news evaluation and scientific-data awareness (Lämmer & Ohl, 2026; Robakiewicz et al., 2026).

The preventive-education results reveal a more consequential gap. Primary students reported the greatest exposure to prevention measures, but ratings were not high in absolute terms, and perceived instruction declined in Secondary Education before partially recovering in Baccalaureate. One tentative curricular interpretation is that Primary Education's cross-curricular and pastoral structure may facilitate drills, family communication, and practical safety activities, whereas Secondary Education's subject fragmentation may weaken continuity. In Baccalaureate, more advanced hazard content may reappear in selected subjects without necessarily reaching all students or translating into practical protocols. This interpretation is plausible in light of the national and regional curricula, but the study did not observe lessons, analyse school plans, or audit implementation; it should therefore be treated as a hypothesis for further research rather than a causal explanation.

H2 is broadly, but not uniformly, supported. Older students generally attributed greater importance to climate-sensitive hazards and stronger influence to climate change and human activity. The clearest result was the moderate stage effect for climate-change attribution to drought, a hazard of high relevance in Mediterranean environments. At the same time, volcanoes showed no stage difference in climate-change attribution and earthquakes showed only a negligible effect. This differentiation may be educationally positive because it is consistent with students distinguishing between climate-sensitive and geophysical hazards. However, the same pattern could also reflect lower salience or familiarity of geophysical hazards rather than accurate causal understanding.The observed effects were nevertheless mostly negligible or small. With a sample of 985, statistical significance can occur even when the practical separation between stages is limited. Educational stage is therefore one influence among many, alongside local experience, family discussion, school practice, media exposure, teacher expertise, and individual interest. The non-random sample further limits population inference. This finding suggests that improving disaster-risk education requires more than curriculum reform. It also depends on teacher training, coordinated school planning, locally relevant learning, and helping students critically assess the digital information they encounter about hazards. The results support the identification of within-sample patterns, not claims that all Primary, Secondary, or Baccalaureate students in Spain would respond in the same way.

Taken together, the findings indicate a gap between conceptual awareness and practical preparation. Students increasingly recognise climate and human influences, yet they report limited and uneven prevention teaching. This matters for the Sendai Framework and for SDG Targets 4.7, 11.b, and 13.3, all of which require education systems to connect knowledge with resilience, early warning, preparedness, and informed action. In Valencia and Murcia, where schools coexist with floods, heat, drought, wildfire, seismicity, and coastal or geomorphological risks, curricular integration should be territorially specific while maintaining a coherent progression across stages.

6. Implications and Recommendations

6.1. Curriculum design and educational practice

The recommendations below are evidence-informed implications derived from the observed patterns; they are not causal prescriptions and should be adapted to local hazards, school capacity, and curricular requirements. The central design principle is progression. Preventive education should not be concentrated in one-off awareness days or repeated at the same level of complexity. It should develop from recognition and simple protective routines in Primary Education, to explanation, source evaluation, mapping, and scenario-based decision-making in Secondary Education, and to critical analysis of uncertainty, territorial planning, and public policy in Baccalaureate (Figure 1).

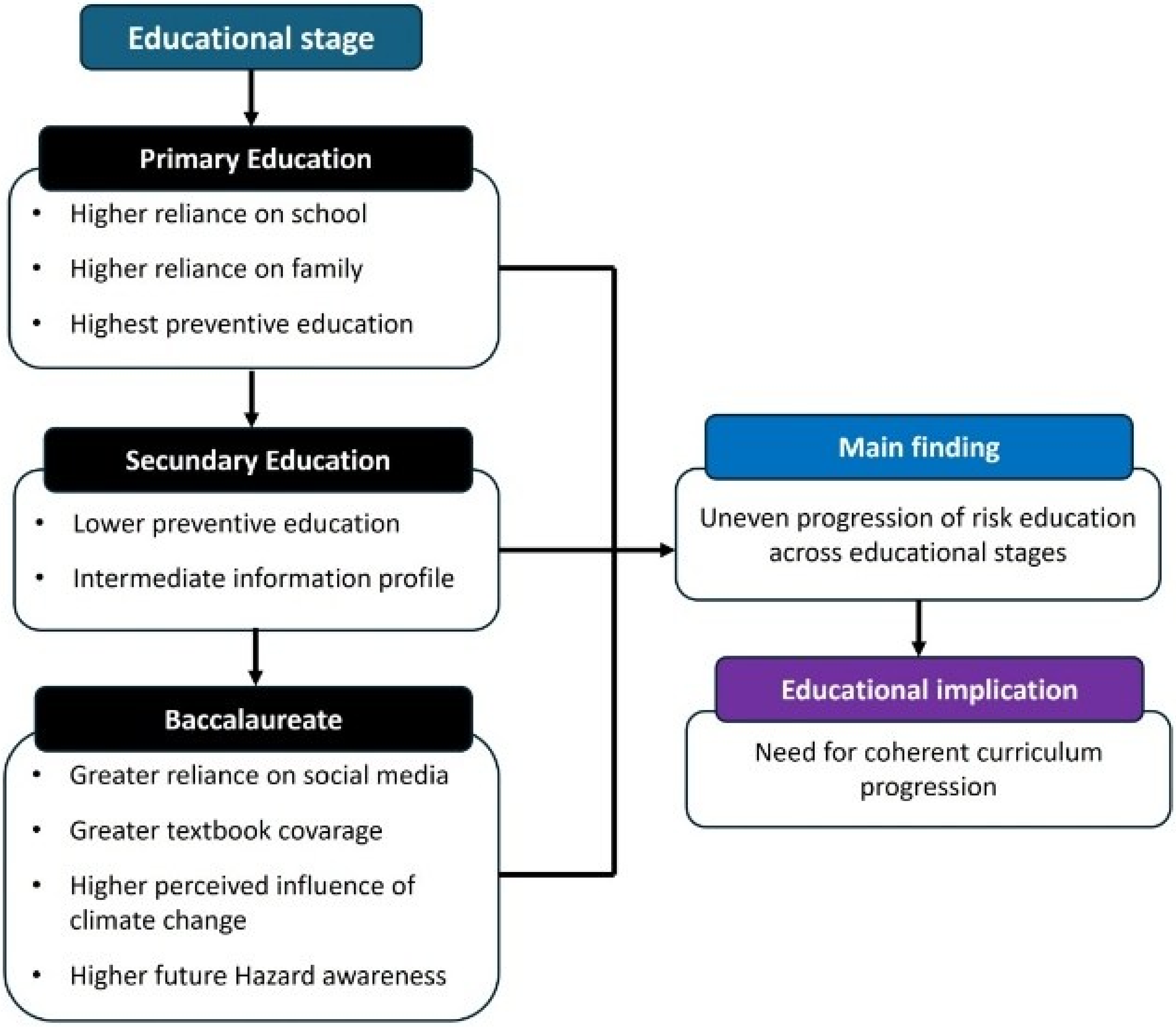

Figure 1. Progression of Risk Education Across Educational Stages (Source: own elaboration)

Curricular integration also requires alignment between intended content, classroom tasks, school emergency plans, and assessment. Knowledge of causes should be assessed alongside the ability to interpret warnings, identify exposed places, select appropriate actions, and justify decisions. Local civil-protection agencies, municipalities, families, and universities can contribute data, maps, drills, and authentic cases, but the school should retain responsibility for sequencing and evaluating learning rather than outsourcing risk education to occasional external activities.

6.2. Teacher education and policy

Teacher education is the enabling condition for this progression. Initial and continuing programmes should strengthen geography teachers' pedagogical content knowledge for hazards and climate change: selecting powerful geographical knowledge, diagnosing misconceptions, using local data and GIS, communicating uncertainty, teaching protective protocols, and designing enquiries that connect physical processes with vulnerability and planning (Favier et al., 2021; He et al., 2024; Smit et al., 2023). Because risk education crosses subjects and pastoral structures, curriculum leadership and collaborative planning are also necessary (Mitchell et al., 2022).

At European level, these competencies can be embedded in teacher-education standards and professional-learning modules rather than treated as optional environmental enrichment. A common framework could specify minimum capabilities - hazard-process knowledge, place-based risk analysis, media and data literacy, scenario pedagogy, inclusive emergency communication, and evaluation of action competence - while allowing national and regional adaptation. This would operationalise SDG 13.3, whose monitoring explicitly includes the extent to which education for sustainable development is mainstreamed in policy, curricula, teacher education, and student assessment.

For policymakers, the results support three practical priorities: require an explicit progression for disaster-risk education across stages; provide schools with locally relevant, quality-assured teaching resources and risk maps; and monitor not only whether hazards appear in curricula but whether students learn preventive actions and can evaluate information. In the study regions, post-2024 reconstruction and resilience initiatives provide an opportunity to connect schools with municipal planning and civil protection while avoiding short-lived responses driven only by the latest disaster. Table 5 summarises the resulting evidence-informed recommendations by educational stage.

Table 5. Evidence-informed recommendations by educational stage

Stage/scope	Curricular emphasis	Illustrative implementation and assessment
Primary Education	Local hazard vocabulary; distinction between hazard and safe/unsafe situations; basic climate-change links; family and community roles.	Simple local risk maps, picture-based scenarios, family-school activities, routine drills, action cards, and age-appropriate source checks. Assess recognition and correct protective action.
Secondary Education	Systematic annual progression in physical and human geography; vulnerability, exposure, resilience, warning systems, and critical digital-media literacy.	Local GIS or map enquiries, verification of social-media claims, comparison of official and informal sources, scenario-based emergency decisions, and reflection after drills. Assess evidence use and action competence.
Baccalaureate	Probabilistic reasoning, uncertainty, attribution, territorial planning, risk governance, and differentiation between climate-sensitive and geophysical hazards.	Analyse local datasets and risk maps, evaluate planning alternatives and public policy, critique scientific and media claims, and communicate recommendations to authentic audiences. Assess reasoned judgement and disciplinary accuracy.
Across stages	A documented progression for risk literacy and preventive education, coordinated with the whole-school safety plan and the hazards of the local territory.	Shared terminology, interdisciplinary planning, periodic review of protocols, accessible resources, links with civil protection, and assessment that combines knowledge, source evaluation, and demonstrated response skills.

Note: Recommendations are derived from the present sample and the reviewed literature; they should be adapted to territorial risk profiles and evaluated before wider implementation.

7. Limitations and Future Research

The first limitation is sampling. Participants were recruited through convenience and professional access rather than a probability design. Selection probabilities are unknown, school-level coverage cannot be fully reconstructed from the available documentation, and representativeness cannot be assessed. The p values therefore do not support design-based generalisation to all students in Valencia, Murcia, Mediterranean Spain, or Spain. They are best read as descriptive evidence of distributional differences in this sample (Hirschauer et al., 2020).

Second, the study is regionally bounded and based on self-report. Responses may reflect memory, social desirability, acquiescence, age-related comprehension, eco-anxiety, recent hazard experience, and current media narratives. Perceived textbook coverage and preventive education are not equivalent to content analysis, classroom observation, or measured competence. The aggregate Cronbach's alpha does not replace construct-specific validation of the distinct item blocks. Another limitation is that no formal attention-check procedures were implemented for this questionnaire administered to young participants. Therefore, inattentive or acquiescent responding cannot be entirely ruled out. Future studies should incorporate response-quality indicators.

Third, the pooled cross-sectional design does not separate age, educational stage, cohort, school, region, or collection-year effects and does not establish developmental or causal change. The dataset did not support school-level multilevel modelling, and no post-hoc pairwise comparisons were available after the omnibus Kruskal-Wallis tests. In addition, no formal correction for multiple comparisons was applied across the numerous Kruskal-Wallis tests reported in Appendix A. Consequently, statistically significant findings with borderline p values and negligible effect sizes should

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be interpreted cautiously. Finally, the study did not evaluate the accuracy of the information sources students used, the quality of school emergency plans, or whether students could perform the protective actions they reported learning.

Besides, future research should address the methodological challenge of incorporating schools located in the southern districts of Valencia—the area most severely affected by the 2024 cut-off low. Including these centres will allow for a more comprehensive analysis of how recent extreme weather events shape students' perceptions, emotional responses, and climate-related learning processes. Moreover, expanding the sampling framework to systematically compare post-disaster and non-affected contexts could provide valuable insights into the temporal dynamics of hazard salience, climate attribution, and emotional literacy in educational settings.

Future research should use probability-based or systematically stratified multi-region samples where feasible and report school-level recruitment and participation rates. Longitudinal or repeated-cohort designs could separate developmental change from cohort effects. Mixed-method studies should combine questionnaires with interviews, focus groups, classroom observation, textbook and curriculum audits, analysis of students' social-media information environments, and performance-based emergency scenarios. Intervention studies could test whether local GIS enquiries, source-verification routines, drills with structured debriefing, and teacher professional development improve both disciplinary understanding and action competence. Age-equivalent scale validation and multilevel analysis should be included when the sampling and data structure permit.

8. Conclusions

Among the participating students, preventive education was perceived as strongest in Primary Education, whereas reliance on social media and awareness of climate-sensitive hazards generally increased towards Baccalaureate. The pattern was not uniform, and most stage effects were small. The study therefore points to an uneven educational progression rather than a simple improvement or decline with age.

The central contribution is the identification of a gap between awareness and preparedness. Students often recognised the future relevance of climate change and human activity but reported limited, inconsistent instruction on preventive action. Geography education can address this gap by integrating local hazard knowledge, vulnerability and territorial planning, warning interpretation, practical protocols, and critical evaluation of digital information across the full school sequence.

A resilient curriculum should enable students not only to explain why hazards occur, but also to judge information and act appropriately before, during, and after an emergency. In Mediterranean regions increasingly affected by climate-related hazards, resilient education is not only about teaching more content on natural hazards. It is about helping students gradually develop the geographical knowledge, critical thinking, and practical skills they need to understand, anticipate, and respond effectively to future risks.

Funding: This research was funded by the R+D+i project "INCLUCOM-Curricular models and historical-geographical competences of teachers for the construction of inclusive identities" (PID2021-122519OB-I00), funded by MCIN/AEI/10.13039/501100011033/ and by "ERDF A way of making Europe".

Institutional Review Board Statement: Under the institutional rules applicable at the authors' university, anonymous non-health opinion and perception questionnaires do not require review by the health-research ethics committee; consequently, no approval number was issued. The study followed the consent, anonymity, confidentiality, and data-protection procedures described in Section 3.4.

Informed Consent Statement: Families received prior information and the consent procedure required by the participating institutions was followed. Students received an age-appropriate explanation and participation was voluntary.

Data Availability Statement: The aggregate data required to evaluate the reported results are presented in the manuscript and Appendix A. Access to participant-level data is restricted under the study's data-protection arrangements; enquiries should be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Detailed Kruskal-Wallis Results

The appendix consolidates the detailed inferential output removed from the main Results section. Mean ranks are reported for Primary Education (P), Secondary Education (S), and Baccalaureate (B).

Table A1. Kruskal-Wallis results for information sources (Item 5)

Outcome/hazard	P mean rank	S mean rank	B mean rank	H	p	epsilon-squared
Family/friends	537.76	455.45	507.95	17.981	< 0.001	0.016
Social media/Inter-net	494.93	464.46	567.25	17.683	< 0.001	0.016
Television	507.75	474.72	514.08	4.038	0.133	0.002
School	566.09	450.57	465.79	36.060	< 0.001	0.035

Note. N = 985 for all outcomes. Epsilon-squared = max[0, (H - k + 1)/(N - k)], with k = 3.

Table A2. Kruskal-Wallis results for preventive education (Item 8)

Outcome/hazard	P mean rank	S mean rank	B mean rank	H	p	epsilon-squared
Hail	599.71	429.56	457.35	88.132	< 0.001	0.088
Heat and cold waves	601.14	423.64	470.73	82.023	< 0.001	0.081
Torrential rain/flooding	572.92	437.40	488.41	47.079	< 0.001	0.046
Earthquakes	574.93	446.40	459.85	47.270	< 0.001	0.046
Snowstorms	573.30	441.89	475.40	63.260	< 0.001	0.062
Volcanoes	592.87	444.62	429.58	75.372	< 0.001	0.075
Windstorms	587.40	430.33	479.37	65.226	< 0.001	0.064
Droughts	579.91	447.74	446.44	51.646	< 0.001	0.051
Forest fires	574.89	439.35	479.22	47.895	< 0.001	0.047

Note. N = 985 for all outcomes. Epsilon-squared = max[0, (H - k + 1)/(N - k)], with k = 3.

Table A3. Kruskal-Wallis results for textbook coverage (Item 9)

Outcome/hazard	P mean rank	S mean rank	B mean rank	H	p	epsilon-squared
Hail	517.38	447.62	569.29	30.152	< 0.001	0.029
Heat and cold waves	540.78	440.31	543.42	32.787	< 0.001	0.031
Torrential rain/flooding	494.97	458.47	583.55	25.710	< 0.001	0.024
Earthquakes	534.95	426.96	591.36	56.273	< 0.001	0.055
Snowstorms	499.85	453.95	586.34	32.034	< 0.001	0.031
Volcanoes	557.17	431.55	535.25	45.061	< 0.001	0.044
Windstorms	524.33	442.00	567.89	33.206	< 0.001	0.032
Droughts	513.86	470.98	512.35	5.732	0.057	0.004
Forest fires	518.38	463.90	522.82	10.028	0.007	0.008

Note. N = 985 except windstorms (N = 984; Secondary Education n = 472). Epsilon-squared = max[0, (H - k + 1)/(N - k)], with k = 3.

Table A4. Kruskal-Wallis results for perceived climate-change influence (Item 14)

Outcome/hazard	P mean rank	S mean rank	B mean rank	H	p	epsilon-squared
Hail	438.11	485.13	622.10	50.853	< 0.001	0.050
Heat and cold waves	449.88	486.24	595.99	35.708	< 0.001	0.034
Torrential rain/flooding	466.27	476.44	590.65	26.884	< 0.001	0.025

https://doi.org/10.48088/ejg.a.mor.17.1.284.299

Outcome/hazard	P mean rank	S mean rank	B mean rank	H	p	epsilon-squared
Earthquakes	526.56	467.51	496.92	9.041	0.011	0.007
Snowstorms	440.87	502.09	570.31	26.275	< 0.001	0.025
Volcanoes	513.30	478.53	492.80	3.118	0.210	0.001
Windstorms	496.06	470.17	549.42	10.429	0.005	0.009
Droughts	385.43	528.38	607.06	90.218	< 0.001	0.090
Forest fires	438.81	496.72	589.01	34.870	< 0.001	0.033

Note. N = 985 for all outcomes. Epsilon-squared = max[0, (H - k + 1)/(N - k)], with k = 3.

Table A5. Kruskal-Wallis results for perceived human influence (Item 15)

Outcome/hazard	P mean rank	S mean rank	B mean rank	H	p	epsilon-squared
Hail	458.35	486.89	577.59	21.977	< 0.001	0.020
Heat and cold waves	445.95	506.27	548.89	17.921	< 0.001	0.016
Torrential rain/flooding	496.40	469.18	551.47	11.221	0.004	0.009
Earthquakes	516.13	466.18	521.02	8.696	0.013	0.007
Snowstorms	485.57	481.64	536.02	5.347	0.069	0.003
Volcanoes	514.33	474.67	501.32	4.349	0.114	0.002
Windstorms	491.24	489.49	506.06	0.473	0.789	0.000
Droughts	469.83	487.32	553.94	11.188	0.004	0.009
Forest fires	441.52	495.95	585.80	32.800	< 0.001	0.031

Note. N = 985 except snowstorms (N = 984; Baccalaureate n = 172). Epsilon-squared = max[0, (H - k + 1)/(N - k)], with k = 3.

Table A6. Kruskal-Wallis results for future hazard salience (Item 16)

Outcome/hazard	P mean rank	S mean rank	B mean rank	H	p	epsilon-squared
Hail	463.77	491.32	554.89	12.328	0.002	0.011
Heat and cold waves	457.75	503.61	533.06	10.568	0.005	0.009
Torrential rain/flooding	444.76	499.31	570.27	25.068	< 0.001	0.023
Earthquakes	478.51	484.57	544.43	7.254	0.027	0.005
Snowstorms	511.41	471.61	515.41	5.422	0.066	0.003
Volcanoes	537.26	467.23	476.71	13.224	0.001	0.011
Windstorms	497.35	475.43	532.51	5.543	0.063	0.004
Droughts	419.96	508.69	593.23	50.174	< 0.001	0.049
Forest fires	421.82	508.32	590.59	50.469	< 0.001	0.049

Note. N = 985 for all outcomes. Epsilon-squared = max[0, (H - k + 1)/(N - k)], with k = 3.

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