Journal of Hazard Literacy
eISSN 3091-6402

Original Article
J. Hazard Lit. 2025;1(2):1-16
https://doi.org/10.63737/jhl.25.0022

Socioscientific issues as a moral context for hazard literacy and disaster education

Dana L. Zeidler*
Department of Teaching and Learning, College of Education, University of South Florida, Tampa, FL, USA

Received: Jun 15, 2025
Revised: Jul 31, 2025
Accepted: Aug 13, 2025

***Corresponding author**
Dana L. Zeidler
Department of Teaching and Learning, College of Education, University of South Florida, Tampa, FL, USA
Tel: +1-813-974-0608
E-mail: zeidler@usf.edu

ORCID
Dana L. Zeidler
https://orcid.org/0000-0002-4250-4982

Conflict of Interest
No potential conflict of interest relevant to this article was reported.

Funding sources
Not applicable.

Acknowledgements
Not applicable.

Availability of data and material
The authors confirm that data supporting the findings of this study are available within the article.

Authors' contributions
The article is prepared by a single author.

Ethics approval and consent to participate
Not applicable.

Abstract

Disaster education is critical for fostering community resilience, but it often struggles to engage learners deeply with the complex, real-world dimensions of hazards. This paper explores the potential of socioscientific issues (SSI) as a pedagogical context to enhance disaster education. SSI, which involve complex, open-ended problems with conceptual, procedural, and ethical components, provide a rich framework for developing critical thinking, decision-making skills, and civic engagement—all vital for effective disaster preparedness and response. I will define SSI, highlight current limitations in hazard literacy/disaster education, and propose how integrating SSI can promote a more holistic understanding of disaster phenomena, encourage ethical reasoning regarding mitigation and adaptation strategies, and empower individuals to become active participants in building safer communities. Hence, this paper argues that hazard literacy education, as well as disaster education, can be instantiated with an SSI-based approach leading to more meaningful, relevant, and impactful disaster education.

Keywords: socioscientific issues, hazard literacy education, epistemic insight, ethics, scientific literacy

Introduction

The escalating global impact of disasters, driven by climate change, urbanization, and socioeconomic vulnerabilities, underscores the urgent need for effective disaster education. Modern disasters are characterized by their increasing frequency, intensity, and complexity, often manifesting as cascading events or compound risks that transcend traditional hazard categories [1]. This demands a populace equipped not just with basic safety knowledge, but with advanced critical thinking, adaptive problem-solving skills, and a nuanced understanding of the systemic factors contributing to disaster risk. Traditional disaster education often focuses on factual knowledge dissemination and procedural drills, such as evacuation routes, risk reduction, or first aid techniques, and the like [2,3]. While important for foundational safety, this approach can sometimes fall short in equipping individuals with the nuanced understanding, critical thinking abilities, and ethical considerations necessary to navigate the multifaceted challenges posed by modern disasters. This is because it frequently neglects the underlying social, economic, and political drivers of vulnerability, leading to a superficial engagement with the topic. Disasters are not merely natural phenomena; they are deeply intertwined with societal structures, economic decisions, political policies, and ethical

dilemmas, making them inherently a sociocultural problem in nature. In fact, some argue that while hazards may be natural, disasters are not in the sense that many are quite predictable with respect to the communities that experience them, but an indifference to marginalized or discriminated groups who have inequitable access to resources and support [4]. This is tantamount to a kind of moral indifference, which is both unnatural in the human sense of the word humanity, and unacceptable to those who understand the root of eudaimonia. It is one thing to evaluate probabilities of risks when it entails events that lead to natural hazards such as typhoons, earthquakes, or hurricanes, for example, factoring in technocratic buffers to reduce it, and study the natural scientific causes that bring them about; but it is another to recognize the inherent fundamental right of human flourishing and developing agency at a grassroots level of community. Doing so, is what I have referred to as thinking 'scientifically responsibly.' The aim of responsible scientific thinking is to cultivate conscientious scientific practices for all students. Conscientious scientific practices may be understood as evoking attitudes and actions that clearly demonstrate great care and attention to any decision to be rendered. The important point here is to understand that such decisions necessitate not only technical competence, but *moral aptitude* as well. And in such a world, there is no room for any kind of moral indifference. This is where the socioscientific issues (SSI) framework may play a role in the pedagogical practices of science education proper, and disaster education literacy in particular. SSI is directed at developing responsible scientific thinking because it is wed to the imbuement of moral aptitude.

SSI are controversial, complex, and often ill-structured problems that involve a conceptual understanding of science and technology, as well as an appreciation of the social, ethical, and moral implications of scientific knowledge and technological advancements [5,6]. Typical examples in science education include climate change, genetic engineering, energy policy, and public health crises. Engaging with SSI requires learners to analyze diverse perspectives, evaluate evidence, make informed decisions, and consider the societal ramifications of scientific and technological developments. This pedagogical approach moves beyond the mere acquisition of scientific facts to cultivate a deeper form of functional scientific literacy (FSL), one that empowers citizens to critically engage with science in their daily lives but necessarily doing so with a due regard to moral and ethical considerations.

The present paper proposes that framing disaster education within an SSI context can significantly enhance its effectiveness. By treating disasters as SSI, learners can explore the scientific underpinnings of hazards (e.g., meteorology, geology, seismology), the technological solutions for mitigation and warning (e.g., early warning systems, resilient infrastructure), and the profound social, economic, political, and ethical dimensions of vulnerability, preparedness, response, and recovery. Wang prudently combines a vision of hazard and disaster literacy, which I will refer to as H/D/L, and aligns that vision, at least tacitly, with the SSI framework, extending the H/D/L concept to examining the structural factors that put vulnerable populations at risk, and calls for a justice-oriented framing of understanding the risks of human choices through a democratic, ethical lens [7]. This approach fosters deeper engagement, critical thinking, and responsible citizenship, moving beyond rote memorization to cultivate truly resilient individuals and communities capable of adaptive decision-making in complex and uncertain environments. But allow me to reemphasize this point in the strongest possible way that I can convey: Any pedagogical inquiry into SSI, and by extension, H/D/L, is fundamentally, a moral endeavor. It must lead to providing the educational conditions under which moral inquiry may occur. It must also lead to the formation of epistemic insights into the issues at-hand tempered by conscious, character and care [8,9].

Understanding Socioscientific Issues (SSI)

SSI represent a pedagogical approach that integrates scientific concepts with social, ethical, and moral considerations. Rooted in science education reform movements that advocate for scientific literacy and responsible citizenship, SSI aim to prepare citizens to make informed decisions about complex issues that have scientific dimensions but also significant societal implications. The theoretical underpinnings of SSI draw from constructivism, argumentation theory, and socio-moral reasoning, emphasizing active learning and the development of higher-order cognitive and moral skills. A summary of the essential characteristics and features of SSI include:

- Controversial and Open-Ended: There are often no single "right" answers, and multiple valid perspectives exist, requiring learners to weigh evidence, values, and potential consequences. This inherent ambiguity mirrors real-world decision-making.
- Scientifically Based with Social Relevance: They involve core scientific concepts and data but are embedded within real-world social contexts, directly impacting individuals, communities, and global systems. This connection makes learning more meaningful and relevant.
- Ethical and Moral Dimensions: Decision-making often involves grappling with ethical dilemmas, conflicting values, and the moral consequences for various stakeholders. Learners are challenged to consider principles of justice, equity, and responsibility.
- Requires Critical Thinking and Argumentation: Learners must analyze information from diverse sources, evaluate claims for credibility and bias, construct coherent arguments, and justify their positions using evidence and reasoning. This fosters epistemic cognition and logical thought.
- Promotes Civic Engagement: Engagement with SSI encourages learners to understand their role as citizens in addressing societal challenges. It cultivates a sense of agency and responsibility to participate in public discourse and decision-making processes.
- Interdisciplinary and Transdisciplinary: SSI often draw upon knowledge from various disciplines beyond science, including sociology, economics, political science, history, and ethics. This interdisciplinary nature reflects the interconnectedness of real-world problems.

In an SSI-based learning environment, students are typically presented with a real-world scenario or dilemma, often through case studies, news articles, or simulated events. They engage in collaborative research, structured discussion, debate, and reflective decision-making, often culminating in the development of a reasoned position, a proposed solution, or a policy recommendation. Common instructional strategies include, for example, dilemma-based learning, role-playing, Socratic seminar discussions, variations of debate formats, (e.g., town hall meeting simulations, policy debates, scientific and moral arguments from multiple stakeholder perspectives), informal place-based and/or augmented reality experiences, and the construction of argumentative essays. The emphasis is not just on understanding scientific facts, concepts, and principles, but on using those to navigate complex societal problems, fostering socio-moral reasoning and an appreciation for the complexities of scientific knowledge application. In such cases, the teacher serves more in a facilitative/exploratory role than a didactic one [10–16].

Challenges in Traditional Hazard / Disaster Education

Traditional hazard and disaster education have ranged from targeting adults with information

to having school-aged children prepare for action if eventualities turn to real-life practices. For example, the 2005 to 2015 Hyogo Framework for Action aimed to cultivate a culture of safety and resilience at all levels through disaster education [17]. The goal was to lessen the negative social and economic effects of hazards. Historically, these educational initiatives and media campaigns primarily focused on adults, providing information about disaster risks and encouraging family preparedness through actions like developing emergency plans, acquiring insurance, and stockpiling essential supplies. Despite these sustained efforts, household preparedness levels have remained consistently low, even as the financial and human costs of catastrophic disasters have risen. This suggests that tradition public education strategies aren't effectively motivating adults to take necessary preparedness measures. In responding to this, emergency management agencies, schools, and non-governmental organizations are increasingly targeting children, and rightfully so, for disaster education. The United Nations Children's Fund (UNICEF) highlights that these programs aim for a shift in understanding as well as behavioral changes towards a more proactive preventative approach to disasters. Reports from the U.S. Federal Emergency Management Agency (FEMA) and UNICEF detail a variety of global disaster education programs for children, including formal and informal initiatives within communities, schools, and extracurricular settings, all supported by public or private funding. This growing investment reflects an international agreement that educating children enhances individual and community resilience to disasters [18,19]. However, despite this consensus, many experts note a significant lack of formal evaluation regarding these programs' effectiveness in achieving desired learning and behavioral outcomes. Evaluations of disaster education programs for children suggest that while disaster education for children may increase their knowledge, there's limited evidence showing how these programs actually help children contribute to household preparedness, boost their self-protection skills, or make them more likely to prepare for disasters as adults. Beyond needing to develop better program theories and ways to measure meaningful outcome indicators, researchers need to explore other areas in the future.

Thus, conventional H/D/L education, while foundational for basic awareness, often encounters several limitations that can hinder its comprehensive and sustained impact, particularly in the face of increasingly complex hazards. It is also not entirely clear if the impetus for H/D/L lies within governmental and community agencies, and/or within school systems. Even within the latter, the nature of pedagogical teaching and learning is unsystematic and likely not congruent with best practices of science education inquiry [2,7,20].

Much of traditional H/D/L education relies on didactic methods such as lectures, informational brochures, and rote drills. This often leads to passive reception of information rather than active engagement, critical inquiry, or the development of adaptive skills. Learners may memorize facts without truly understanding the underlying principles or their application in dynamic situations. From the students' perspective, there may be a lack of contextual relevance inasmuch as generic information and universal guidelines may not resonate with the specific vulnerabilities, cultural contexts, socio-economic realities, or hazard profiles of diverse communities. A one-size-fits-all approach fails to address the unique challenges faced by marginalized groups, indigenous populations, or those in specific geographical regions, leading to disengagement and ineffective preparedness.

Traditional curricula tend to overlook the complex ethical dilemmas, power dynamics, and social inequalities that profoundly shape disaster impacts and recovery. Issues such as equitable resource allocation during response, the ethics of mandatory evacuations, the disproportionate impact on vulnerable populations, or the moral responsibilities in post-disaster reconstruction are rarely explored in depth, the impetus for searching for ethical and social exploration in

those contexts are lost. Furthermore, the focus on individual action over collective responsibility tends to be conflated. While individual preparedness (e.g., having a first-aid, an action plan, etc.) is crucial, an overemphasis on personal readiness can obscure the systemic and collective responsibilities in disaster risk reduction. It often fails to highlight the role of governance, urban planning, infrastructure development, and community-led initiatives in building resilience, thereby limiting learners' understanding of their broader civic role. Collective action is needed to best mitigate ecological, global challenges, account for social vulnerability, respond to socio-technological issues and socio-natural disasters. This is best thought of as a type of collaborative network that fosters community resilience [21–23]. This is consistent with prior SSI work focusing on what it means to think (scientifically) responsibly -- whereby viewing our ever-fluctuating social and environmental contexts through a lens of common social tapestries (structures) we can push ourselves to think and act responsibly as collective human beings enmeshed in a shared human condition [24].

Additional challenges that confront H/D/L education are similar to the kinds of challenges that science educators face when attempting to break the norms of conventional science teaching. A few cases in point include the insufficient development of decision-making skills: Traditional methods rarely provide opportunities for learners to practice complex decision-making under uncertainty, ambiguity, and time pressure, which are inherent in both SSI and real disaster scenarios. The focus on prescribed actions leaves little room for developing the adaptive capacity needed when unforeseen circumstances arise. As with other science education challenges, there is the problem of having a disconnect from real-world policy and planning. For example, disaster education frequently operates in a vacuum, failing to effectively link individual actions to broader community planning, policy development, or advocacy efforts. Learners may not understand how scientific information translates into public policy, how community voices can influence hazard mitigation plans, or how they can contribute to long-term resilience strategies [25]. Furthermore, disaster education can sometimes be treated as a standalone, episodic topic, often triggered by a recent event, rather than an ongoing process integrated into daily life, civic responsibility, and continuous learning. This episodic approach hinders the sustained development of preparedness culture and long-term behavioral change in both individuals and social systems [26].

Socioscientific Issues as a Context for Hazard and Disaster Literacy Education

We can see from sections 3 and 4 above, that H/D/L education tends to be primarily concerned with educating people about the risks, causes, impacts, and management of disasters (natural or man-made). It aims to increase awareness, preparedness, and response strategies for various types of disasters, such as earthquakes, floods, hurricanes, or pandemics. Its primary pedagogical goal is to prepare students and communities for disasters by building knowledge on risk reduction, emergency management, and assess practical options for intervention strategies and adaptive responses. In contrast, SSI education tends to focus on complex, real-world issues that intersect science and society, while promoting ethics and resolving moral tensions. These issues often involve controversial topics like climate change, biotechnology, genetic engineering, public health, and environmental degradation. Engaging in such spaces requires SSI pedagogy that encourages students to analyze the social, political and moral aspects of such issues. While both H/D/L and SSI approaches encourage critical thinking, interdisciplinary learning, and

engagement with real-world issues, H/D/L is often more immediate and practical in its focus, whereas SSI explores complex, multifaceted scientific issues that require deeper ethical and social analysis.

My central proposition is that integrating SSI into H/D/L education offers a powerful pedagogical framework to address the aforementioned challenges, fostering a more dynamic, relevant, and impactful learning experience that cultivates both scientific literacy and responsible citizenship. I make no claims that implementing an SSI approach will be a panacea for all the complex educational issues that are presented under H/D/L education, because its implementation does require forethought and a deliberate commitment to understand its presuppositions, as well as understanding the intellectual and developmental talents of students, and the public at-large. If implemented only as prescriptive procedural pedagogy, the SSI framework can be made infertile by infertile minds. If implemented in a manner that frames this approach as a moral inquiry into things that matter, a student-oriented sociocultural approach that connect students and the public to the nature of scientific discourse, argumentation, creativity, open-mindedness, citizenship responsibility, and development of virtue, can then provide the conditions necessary for a transformational shift to occur can in the learning of complex SSI. The extent research on SSI frameworks clearly demonstrate transformational shifts for students because of the many sociocultural factors present that lead to personal relevance and agency in the inquiry and learning process [27–29].

Fostering critical thinking and decision-making

H/D/L topics are inherently complex, requiring rapid decision-making under pressure, uncertainty, and often with incomplete information. SSI approaches provide a safe environment for learners to practice these crucial skills. By analyzing disaster scenarios as SSI (e.g., "Should a city invest billions of dollars in a massive seawall, or should it prioritize managed retreat and relocation for communities given rising sea levels and increased storm surges?"), students are compelled to evaluate diverse scientific data (e.g., climate models, geological surveys), consider complex economic costs and benefits, assess profound social impacts (e.g., displacement, cultural loss), and grapple with ethical trade-offs (e.g., protecting property vs. human lives, intergenerational equity). This process develops a range of higher-order thinking skills (epistemic insights), including:

- Information Analysis: Critically evaluating the credibility of sources, identifying biases, and discerning relevant data from misinformation.
- Problem Framing: Defining the core issues, identifying stakeholders, and understanding the multi-dimensional nature of the problem.
- Solution Generation and Evaluation: Brainstorming multiple solutions and systematically assessing their feasibility, effectiveness, and potential unintended consequences.
- Argumentation: Constructing coherent, evidence-based arguments, anticipating counter-arguments, and refining their positions through discourse. These skills are crucial for effective preparedness, response, and recovery.

Sadler and colleagues stress the importance of incorporating these types of epistemic practices in "Next Generation" SSI which would certainly include H/D/L issues. The use of modeling in general, and constructing mechanistic computational models in particular, to frame problems, develop explanations of underlying causes and interconnected processes help learners to better gain the scientific understanding required for informed decision-making [16,30–32]. Further,

there exists excellent research with implications for practice in how students or the public may sensibly evaluate the plethora of information that exists, and discern reasonable sources from mis/disinformation, using pedagogical techniques such as the implementation of strategies like "CARS" (credibility, accuracy, reliability, sources of data and information) and "ESCAPE" (evidence, source, context, audience, purpose, execution) -- where there is a focus on lateral reading across multiple sources to verify the veracity of information [33–36]. In particular, Herman and colleagues have researched and developed implications for practice that provides insight into the level of trust people place in the mainstream scientific community versus sources of misinformation and disinformation that profoundly affects human and environmental health, with potentially disastrous consequences. Their work is very well positioned to instantiate H/D/L in the context of SSI. Teacher instructional materials aimed at cultivating students' sensitivity to spotting mis/disinformation with connections to the Nature of Science in areas of astronomy, biology, chemistry, geology, and physics, stemming from their research are provided by his research team [37].

If the goals of H/D/L education include developing a "metaverse" virtual space, outreach for citizens and minorities, expansive programs and teaching-learning methods, the SSI framework serves as a humanistic conduit for the engagement of "outsiders" into this space. Having the participation of "competent outsiders" which is crucial for the public engagement of science [38]. This is most pressing in the age of mis/disinformation – whether that information if intentionally or unintentionally false or misleading in a "Post Truth" era [39]where it becomes imperative that citizens have the requisite scientific expertise to navigate through turbulent waters of deceptive conspiracy "theories," alternative facts, confirmation bias, and legitimate competing claims [40].

The presuppositions of nurturing ethical reasoning, moral identity and moral action in H/D/L within the context of socioscientific issues

H/D/L education often expose and exacerbate existing social inequalities and present profound ethical dilemmas that demand careful consideration. An SSI approach compels learners to confront these issues head-on, moving beyond a purely technical understanding of disaster management. For example, discussions around who receives aid first in a resource-scarce environment, the ethics of mandatory evacuations versus individual liberty, the moral responsibility of developed nations towards climate-vulnerable communities, or the just allocation of resources in post-disaster reconstruction, compel students to articulate and justify the presuppositions of their ethical stances. Doing so fosters a deeper understanding of important ethical considerations such as:

- Justice and Equity: Examining how disaster impacts and recovery efforts can perpetuate or mitigate social inequalities.
- Human Rights: Considering the fundamental rights of affected populations, including access to shelter, food, water, and medical care.
- Utilitarianism vs. Deontology: Applying different ethical frameworks to complex decisions (e.g., maximizing overall good vs. adhering to moral duties).
- Intergenerational Responsibility: Reflecting on the long-term consequences of current decisions for future generations. This ethical exploration is vital for cultivating compassionate and responsible citizens who can advocate for equitable disaster policies.

While a conceptual understanding of content knowledge is obviously central to being an informed participant in educational or public service programs related to H/D/L, a focus on

content alone to the exclusion of affective domains is problematic on multiple levels [41]; the cultivation of conceptual ecologies is simply incomplete without the due consideration to emotive factors that connect moral identity, moral sensitivity, reason-infused moral emotions, moral adjudication, and moral actions in the process of deriving wholly informed commitments to environmental positions and actions [38]. In examining this problem in more detail, a series of studies examining the impact of emotive/affective factors on students' reasoning and socioscientific perspective (SSP) taking about environmental SSI revealed the significance of an array of emotive reasoning including such factors as apathy (a state of emotional detachment where there's no consideration for the feelings or welfare of others.), passive care (an emotive awareness and concern for the welfare of ecocentric and/or anthropocentric factors but with caveats that serve to psychologically distance oneself from vicariously experiences others' potential suffering) and empathetic dissonance (characterized by intense, visceral emotional reactions related to the well-being of both nature and people). These affective and emotive influences further revealed related moral subcomponents that factored into both ecocentric and anthropocentric orientations toward environmental issues such. Such factors included diffusion of responsibility (shifts their personal responsibility for a problem onto a larger group or abstract concept like "the community" or "nature."), compassion (a deep feeling of concern for the suffering of people and nature, regardless of *the root causes of their* suffering.), guilt (the uncomfortable feeling of shame or regret for not taking action to address negative impacts on people and nature, especially when sustainable solutions exist), anger (feeling empathy for suffering people and nature, coupled with overt frustration or fury directed at a clear cause of that suffering), and righteous indignation (a visceral emotive response toward people and nature -- particularly when perceived inequities or injustices are viewed as root causes) [29,42,43].

The emotive factors described above are bound up in what may be considered a "neo-Aristotelian model of phonetic (practical wisdom) in the context of deriving moral decisions. Here, I advance the claim that to the extent H/D/L is instantiated in a broader SSI framework, phronesis, as an intellectual virtue, depends on both moral and ethical decisions that are tempered by practical wisdom. Practical wisdom is derived from using evidence-based data, information, or reasoning from real-world experiences. Thus, phronesis serves as an anchoring point that connects moral identity, moral emotions, and moral reasoning. Zeidler [27] has advanced a model derived from Krisjansson and others [44,45] that connects practical wisdom with moral decision-making (Fig. 1).

This is a model that fundamentally subsumes the nature and major elements of moral inquiry. I do not mean to suggest that it captures every nuance of a moral inquiry; but it certainly requires, at the very least, the key elements represented here. One can think of the "boxes" as conceptual elements of moral inquiry, while those listed in CAPITAL letters align with current constructs recognized and used for research in the social sciences. In this model, both conceptually and empirically, moral emotions are understood to provide the affective elements that motivate the connection between moral reasoning and action. This understanding aligns with Aristotle's philosophical treatment of phronesis and is consistent with contemporary social scientists' conceptualizations of moral functions. My core interest lies in the dynamic interplay between moral inquiry and moral action. While it may be the case that a given moral action may be executed by random chance, one would think that any deliberate moral action is preceded by an act of conscience specific to a decision to act (or not to act). It is here that moral decision-making precedes moral action, and that the development of moral identity is fostered by cultivating moral sensitivity through reason-induced emotions during the process of evaluating diverse perspectives prior to making and enacting a decision. Furthermore, it is important to

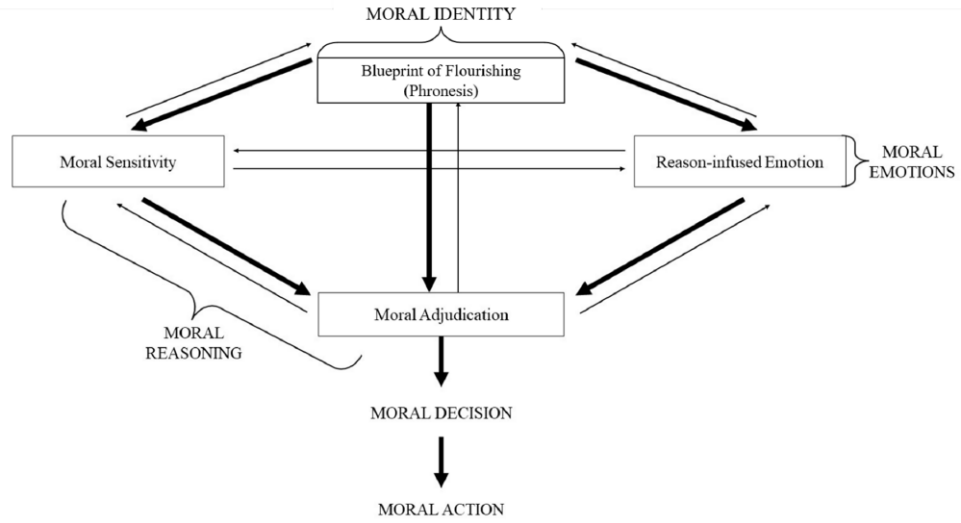

Fig. 1. A Neo-Aristotelian Model of phonetic moral decision-making. Adapted from Kristjansson & Pollard [44] with permission of the copyright holder.

understand that the pathway to moral action is not a linear process; rather these major elements are part of a "system" or network of integrative moral processes that are part and parcel to moral inquiry. The bold arrows merely represent major pathways of the elements preceding an intellectually robust decision. The narrow arrows remind us that the system is not closed, but open to continuous feedback loops. This meta-construction of moral identity ultimately serves as a blueprint for moral action. It also satisfies the cognitive-affective or 'reason- emotion' to action gap bridging the connections among these constructs. Darnell and colleagues emphasize this reciprocal network relationship stating: "…neo-Aristotelians may also point out that the natural conclusion to draw from empirical research on the contributions of moral reasoning, moral identity, and moral emotions to moral behaviour is that while each of these elements is involved in moral behaviour, no one element can bridge the gap on its own." p. 105) [46]. The "blueprint" of phronesis, is the central bond that holds these elements together to work collectively, rather than in isolation with one another, so a mature Moral Identity can flourish and have its day.

The SSI framework is particularly sensitive to these factors, recognizing them as necessary conditions for the growth, practice, and dissemination of human flourishing. This is because the SSI framework offers the intellectual environment required to experience issues demanding practical wisdom, engage in practice, formulate decisions, and gain opportunities to potentially act on those decisions. Hence, the formation of moral identity is predicated on well-planned and deliberate moral actions. From a H/D/L perspective, it would be prudent to consider these factors, at least to some extent, as a central part of any pedagogical model that is meant to ultimately empower students and/or the public – as the public good is only as good to the extent that due consideration of ethical reasoning becomes part of the development of FSL [16,27].

Enhancing civic engagement, relevance and agency

By framing disaster education around contemporary, real-world problems that have direct relevance to learners' lives, communities, and global challenges, SSI can significantly increase engagement. Students are intrinsically motivated when they perceive the direct application of scientific knowledge to societal challenges and when their opinions and decisions are valued in a discussion about complex issues that affect them. This moves disaster education from an abstract

concept to a tangible, personal, and urgent concern. The open-ended nature of SSI allows for diverse perspectives and solutions, making the learning process more dynamic and inclusive. This active engagement fosters deeper cognitive processing and retention, leading to more meaningful learning outcomes compared to passive information absorption.

SSI inherently connect scientific understanding with its societal implications, fostering a holistic view of complex phenomena. For example, in disaster education, this means exploring not just the mechanics of a hurricane (meteorology, physics), but also how urban planning decisions, infrastructure development, socio-economic status, historical land use, and communication systems influence vulnerability and resilience. This interdisciplinary perspective allows learners to grasp the systemic nature of disaster risk, moving beyond a purely scientific or purely social understanding. It helps students understand concepts like risk perception, where scientific data interacts with individual and collective beliefs, values, and experiences to shape how hazards are understood and acted upon. By examining these connections, learners can develop a more comprehensive understanding of why certain communities are more vulnerable and what integrated solutions are required. In this way, learners recognize that they are not merely passive recipients of disaster impacts but active agents in shaping their community's resilience and future. They can explore how scientific information informs public policy, how community advocacy can influence hazard mitigation and emergency planning, and how individual choices contribute to collective safety and sustainability. This fosters a sense of responsibility and empowers them to participate meaningfully in local and broader disaster risk reduction efforts. For example, it moves beyond individual preparedness to collective action, encouraging students to consider their roles in: Policy Advocacy: understanding how to influence local and national disaster policies; Community Organizing: participating in or initiating community-led preparedness and recovery initiatives; and Responsible Consumption: recognizing how their daily actions (e.g., energy use, waste generation) contribute to climate change and thus disaster risk. This cultivation of agency is fundamental to building truly resilient and adaptive societies [47,48].

Bencze and colleagues [49] have provided numerous examples where enhancing civic engagement, relevance and agency can be addressed by what they term a "STEPWISE" pedagogy (which maps on well to H/D/L and SSI) whereby educators provide students with inquiry-based lessons that equip them with the skills and motivation to take thoughtful, collaborative sociopolitical action. The core aim is to tackle harms students identify within the complex interactions of STEM fields, moving from concern to tangible solutions. It further addresses topics such as citizen climate activism, complexities of learning in a socio-cultural context, and fostering community and ecojustice centered on altruistic outcomes for science education. Likewise, others [50] have pointed out that developing SSP is important not only to achieve FSL, but to break down the siloing of traditional curricular models which restrict learners' exposure to connections across entrenched field of specialization. Here, SSP is designed around engagement, moral sensitivity, and perspective-taking, creating educational pathways for students to critically reflect on socioecological challenges and gain deeper insights. This progressive pedagogical approach revealed that it was highly effective in supporting transformational learning among our undergraduate students. This has important implications for science education, particularly for those who teach interdisciplinary topics found in H/D/L education. Such research showcases how a responsible, issue-based curriculum can be structured to empower students, allowing them to truly own their understanding and contribute to discussions around SSI—in essence, exercising epistemic authority.

Conclusion

Framing H/D/L in an SSI context moves beyond traditional methods, fostering deeper understanding, critical thinking, and civic responsibility. This approach engages learners with the complex scientific, technological, social, ethical, and political aspects of disasters, empowering them to become informed, resilient, and active in building safer communities. It cultivates crucial skills like critical inquiry, ethical reasoning, and adaptive decision-making, which are vital for navigating an uncertain world. Despite challenges in teacher preparedness, curriculum integration, and resources, the transformative potential of SSI-based disaster education is clear. To fully realize this, we need more interdisciplinary research, innovative curricula, strong teacher development, and partnerships with disaster management agencies. However, the numerous implications of contextualizing H/D/L within an SSI framework offer a versatile approach to disaster education across various educational levels and contexts. Consider, for example, several concrete examples that can be found in the extant literature [51–56].

- Climate Change Adaptation Debates: Students analyze scientific projections for local climate impacts (e.g., sea-level rise, increased heatwaves, altered precipitation patterns) and debate various adaptation strategies. This could involve a simulated town hall meeting where students, adopting roles of different stakeholders (e.g., climate scientists, urban planners, real estate developers, vulnerable community members), present arguments for or against specific solutions like building massive seawalls, implementing managed retreat programs, developing green infrastructure, or investing in early warning systems. The debate would consider economic feasibility, social equity, environmental consequences, and long-term sustainability.
- Post-Disaster Reconstruction Ethics: Case studies on past disasters (e.g., Hurricane Katrina, the Fukushima earthquake/tsunami, the Haiti earthquake) where profound ethical dilemmas arose during reconstruction can serve as rich SSI. Students could analyze decisions related to equitable land allocation, preventing gentrification, preserving cultural heritage sites versus rapid rebuilding, or the fair distribution of aid and compensation. This would involve examining primary sources, interviewing affected individuals (through simulated scenarios or actual accounts), and developing ethical frameworks to guide future reconstruction efforts.
- Early Warning Systems and Communication: Learners investigate the scientific and technological principles behind early warning systems for hazards like tsunamis, tornadoes, or pandemics. Beyond the technical aspects, they would explore the social challenges of effective communication, including ensuring messages are culturally appropriate, accessible to individuals with disabilities, reach diverse linguistic groups, and overcome issues of public trust or warning fatigue. Students might design a communication strategy for a specific community, considering its unique demographics and communication channels.
- Resource Allocation in Crisis: Simulations or role-playing exercises where students must make difficult decisions about allocating limited resources (e.g., medical supplies, shelter space, clean water, transportation) during a rapidly unfolding disaster. This could involve a scenario where a hospital faces an overwhelming influx of patients, forcing students to prioritize care based on triage principles, ethical guidelines, and available resources, compelling them to justify their choices based on ethical frameworks like utilitarianism or principles of justice.
- Infrastructure Resilience Planning: Students examine the scientific principles of resilient infrastructure (e.g., earthquake-resistant building codes, flood defenses, smart grids)

alongside the social, economic, and political considerations of implementing such projects in different communities. This could involve analyzing a city's current infrastructure vulnerabilities and proposing upgrades, considering the costs, benefits, and potential displacement of residents, or the impact on local economies.

- Public Health Emergencies: Analyzing the scientific basis of disease transmission (e.g., pandemics, outbreaks) alongside the complex ethical implications of public health measures, such as mandatory quarantines, vaccine distribution strategies, contact tracing, and individual liberties versus collective safety. Students could debate the role of government, individual responsibility, and global cooperation in managing health crises, drawing parallels to past epidemics.
- Disaster Tourism and Ethics: Exploring the phenomenon of "dark tourism" or "disaster tourism" in post-disaster zones. Students could debate the ethical implications for affected communities, the potential for exploitation versus economic recovery, and how such sites should be managed to respect victims and promote learning.
- Consider Non-Traditional H/D/L topics such as the impact of media and political ideologies or the impact of ubiquitous reliance that artificial intelligence (AI) systems have on students' ability to think in conceptually deep and sustained ways impacts neural well-being in particular, and human flourishing in general. Such topics may deviate from the "norm" of conventional H/D/L topics, but it can be argued that not paying attention to such unconventional H/D/L topics are, in and of themselves, hazardous and disastrous.

The pervasive and intensifying global impact of disasters, driven by climate change, urbanization, and deep-seated socio-economic vulnerabilities, unequivocally underscores the urgent need for a more robust and nuanced approach to (H/D/L) education. This paper has argued that framing H/D/L within a SSI context represents a transformative pedagogical shift, moving beyond the limitations of traditional, didactic methods. It is also consistent with Park's argument in moving beyond the 'two cultures' of disaster and science education by bridging the gap between them, i.e., how H/D/L and science education can mutually benefit from each other. By engaging learners with the inherently complex scientific, technological, social, ethical, and political dimensions of disasters, an SSI approach empowers individuals to transcend rote memorization and cultivate the critical thinking, ethical reasoning, and civic responsibility essential for building truly resilient and equitable communities. Furthermore, an SSI-based H/D/L education cultivates not only cognitive skills but also a vital moral compass. This is what is meant by a moral inquiry in the context of SSI, for moral inquiry cannot take place in the absence of moral education, and moral education cannot exist in the absence of a blueprint for Phronesis. That is precisely what instantiating H/D/L in the context of SSI achieves. The factors that conventional H/D/L education typically emphasizes tend to be focused on more of the technocratic side of risk reduction and management that align with other important cognitive elements. These elements are necessary but not sufficient conditions for the task of moral inquiry, for the virtuous nature of individuals requires a kind of moral anatomy that includes moral values, moral reasoning, moral emotion, moral identity, etc. (see Fig. 1 above), among other sociocultural factors. Prompting learners to confront issues of justice, equity, and human rights in disaster contexts—such as the disproportionate impact of extreme weather events on lower-income communities or the equitable allocation of aid during resource scarcity, fosters a deeper understanding of both moral responsibility and moral identity. The integration of reason-infused emotional factors with moral reasoning, as highlighted by the neo-Aristotelian model of phronesis, acknowledges that ethical decisions are not solely intellectual exercises but are

also profoundly shaped by empathy, compassion, and a sense of righteous indignation towards injustice. Argumentation in the absence of relevance to students' lives is shallow. Moral reasoning that ignores real-world evidence is fundamentally flawed. Our educational aims should not prioritize one domain (cognitive, affective, behavioral) to the exclusion of others. The holistic approach advanced here ensures that learners develop not just scientific literacy, but a 'functional scientific literacy' tempered by conscience and care, transforming them into ethically informed and engaged citizens.

References

1. Ahamed MS, Sarmah T, Dabral A, Chatterjee R, Shaw R. Unpacking systemic, cascading, and compound risks: a case based analysis of Asia Pacific. Prog Disaster Sci 2023;18:100285. https://doi.org/10.1016/j.pdisas.2023.100285
2. Shaw R, Takeuchi Y, Ru Gwee Q, Shiwaku K. Disaster education: an introduction. In: Shaw R, Shiwaku K, Takeuchi Y, editors. Community, environment and disaster risk management: disaster education. Emerald Group; 2011. p. 1-22.
3. Kitagawa K. Conceptualising 'disaster education'. Educ Sci 2021;11:233. https://doi.org/10.3390/educsci11050233
4. Puttick S, Bosher L, Chmutina K. Disasters are not natural. Teach Geogr 2018;43:118-120. https://www.jstor.org/stable/26538739
5. Zeidler DL, Keefer M. The role of moral reasoning and the status of socioscientific issues in science education: philosophical, psychological and pedagogical considerations. In: Zeidler DL, editor. The role of moral reasoning on socioscientific issues and discourse in science education. Kluwer Academic Press; 2003. p. 7-38.
6. Sadler TD. Informal reasoning regarding socioscientific issues: a critical review of research. J Res Sci Teach 2004;41:513-536. https://doi.org/10.1002/tea.20009
7. Park W. STEM education for transformative hazard literacy: from technological fixes to slow learning. J Hazard Lit 2025;1:e3. https://doi.org/10.63737/jhl.25.0014
8. Zeidler DL. Brute facts about the construction of a framework for socioscientific issues. In: Zeidler DL, editor. A moral inquiry into epistemic insights in science education: personal and global perspectives of socioscientific issues. Springer Nature; 2024. p. 25-37.
9. Zeidler DL, Sadler TD. The role of moral reasoning in argumentation: conscience, character, and care. In: Erduran S, Jiménez-Aleixandre MP, editors. Argumentation in science education: perspectives from classroom-based research. Springer Press; 2007. p. 201-216.
10. Kahn S, Zeidler DL. Using our heads and HARTSS*: developing perspective-taking skills for socioscientific reasoning (*humanities, arts, and social sciences). J Sci Teach Educ 2016;27:261-281. https://doi.org/10.1007/s10972-016-9458-3
11. Zeidler DL, Nichols BH. Socioscientific issues: theory and practice. J Elem Sci Teach Educ 2009;21:49-58. https://doi.org/10.1007/BF03173684
12. Newton MH, Annetta LA. The influence of extended reality on climate change education. Sci Educ 2024;34:825-845. https://doi.org/10.1007/s11191-024-00518-y
13. Herman BC, Newton MH, Zeidler DL. Impact of place-based socioscientific issues instruction on students' contextualization of socioscientific orientations. Sci Educ 2021;105:585-627. https://doi.org/10.1002/sce.21618
14. Namdar B, Karahan E. Socioscientific issues focused teacher education: place-based practices from Türkiye. Springer Nature; 2024.
15. Evagorou M, Nielsen JA, Dillon J. Science teacher education for responsible citizenship:

towards a pedagogy for relevance through socioscientific issues. Springer Nature; 2020.
16. Zeidler DL, Sadler TD. Exploring and expanding the frontiers of socioscientific issues: crossroads and future directions. In: Lederman NG, Zeidler DL, Lederman JS, editors. Handbook of research on science education: volume III. Routledge; 2023. p. 899-929.
17. United Nations. Hyogo framework for action 2005–2015: building the resilience of nations and communities to disasters [Internet]. UNHCR; 2005 [cited 2025 Aug 13]. Available from: http://www.refworld.org/docid/42b98a704.html
18. United Nations Children's Fund. Children and disasters: building resilience through education [Internet]. UNICEF; 2011 [cited 2025 Aug 13]. Available from: http://www.unicef.org/ceecis/Children_and_disasters_Building_resilience_through_education_final.pdf
19. Federal Emergency Management Agency. Youth preparedness catalog: disaster preparedness education programs and resources [Internet]. FEMA; 2016 [cited 2025 Aug 13]. Available from: https://www.ready.gov/sites/default/files/2019-06/youth_preparedness_catalog_508.pdf
20. Kitagawa K. Conceptualising 'Disaster Education'. Educ Sci 2021;11:233. https://doi.org/10.3390/educsci11050233
21. Bixler RP, Lieberknecht K, Atshan S, Zutz CP, Richter SM, Belaire JA. Reframing urban governance for resilience implementation: the role of network closure and other insights from a network approach. Cities 2020;103:102726. https://doi.org/10.1016/j.cities.2020.102726
22. McPhearson T, Andersson E, Elmqvist T, Frantzeskaki N. Resilience of and through urban ecosystem services. Ecosyst Serv 2015;12:152-156. https://doi.org/10.1016/j.ecoser.2014.07.012
23. Gülsoy A, Uyan Y, Özcan E, Durmuş M. The relationship between disaster literacy levels and disaster preparedness among adults. Nat Hazards 2025;121:10667-10681. https://doi.org/10.1007/s11069-025-07225-z
24. Zeidler DL, Berkowitz MW, Bennett K. Thinking (scientifically) responsibly: the cultivation of character in a global science education community. In: Mueller M, Tippins D, Steward A, editors. Assessing schools for generation R (responsibility): a guide for legislation and school policy in science education. Springer; p. 83-99.
25. Hudson B, Hunter D, Peckham S. Policy failure and the policy-implementation gap: can policy support programs help? Policy Des Pract 2019;2:1-14. https://doi.org/10.1080/25741292.2018.1540378
26. National Academies of Sciences, Engineering, and Medicine. Exploring lessons learned from a century of outbreaks: readiness for 2030. In: Proceedings of a Workshop. The National Academies Press; 2019 May 24; Washington, DC.
27. Zeidler DL. Moral inquiry in the practice of socioscientific issues. In: Zeidler DL, editor. A moral inquiry into epistemic insights in science education: personal and global perspectives of socioscientific issues. Springer Nature; 2024. p. 39-64.
28. Nolan E, Zeidler D. Transformational learning for complex socioscientific issues. Res Sci Educ 2025;55:771-791. https://doi.org/10.1007/s11165-025-10264-y
29. Newton MH, Zeidler DL. Developing socioscientific perspective taking. Int J Sci Educ 2020;42:1302-1319. https://doi.org/10.1080/09500693.2020.1756515
30. Sadler TD, Ke L, Peel A. Next generation socioscientific issues education: incorporating practices in SSI learning experiences. In: Zeidler DL, editor. A moral inquiry into epistemic insights in science education: personal and global perspectives of socioscientific issues. Springer Nature; 2024. p. 409-426.

31. Zangori L, Ke L, Sadler TD, Peel A. Exploring primary students causal reasoning about ecosystems. Int J Sci Educ 2020;42:1799-1817. https://doi.org/10.1080/09500693.2020.1783718
32. Zangori L, Peel A, Kinslow A, Friedrichsen P, Sadler TD. Student development of model-based reasoning about carbon cycling and climate change in a socio-scientific issues unit. J Res Sci Teach 2017;54:1249-1273. https://doi.org/10.1002/tea.21404
33. Zeidler DL, Zeidler L, Kahn S. It's debatable: using socioscientific issues to develop scientific literacy, K-12. National Science Teachers Association Press; 2014.
34. UO Libraries. Misinformation, bias and fact checking: mastering media literacy [Internet]. University of Oregon; 2025 [cited 2025 Aug 13]. Available from: https://researchguides.uoregon.edu/medialiteracy/evaluating-sources
35. Herman BC, Poor S, Clough MP, Rao A, Kidd A, De Jesús D, et al. It's not just a science thing: educating future STEM professionals through mis/disinformation responsive instruction. J Res Sci Teach 2024;61:1925-1974. https://doi.org/10.1002/tea.21934
36. Breakstone J, Smith M, Connors P, Ortega T, Kerr D, Wineburg S. Lateral reading: college students learn to critically evaluate Internet sources in an online course. Harvard Kennedy School (HKS) Misinformation Review; 2021.
37. Herman BC. The story behind the science: bring science and scientists to life [Internet]. NSF; 2025 [cited 2025 Aug 13]. Available from: https://eric.ed.gov/?id=EJ930023
38. Feinstein N. Salvaging science literacy. Sci Educ 2011;95:168-185. https://doi.org/10.1002/sce.20414
39. McIntyre L. Post-truth. The MIT Press; 2018.
40. Pimentel D, Osborne J. Misinformation in science: the response of science education. In: Cakmakci G, Tasar MF, editors. Connecting science education with cultural heritage. Contributions from science education research, vol 15. Springer; 2025.
41. Zeidler DL, Newton MH. Using a socioscientific issues framework for climate change education: an ecojustice approach. In: Shepardson DP, Roychoudhury A, Hirsch AS, editors. Teaching and learning about climate change: a framework for educators. Taylor & Francis Online; 2017. p. 56-66.
42. Herman BC, Zeidler DL, Newton M. Students' emotive reasoning through place-based environmental socioscientific issues. Res Sci Educ 2020;50:2081-2109. https://doi.org/10.1007/s11165-018-9764-1
43. Kristjansson K, Darnell C, Fowers B, Moller F, Pollard D. Phronesis: developing a conceptualization and instrument. University of Birmingham: The Jubilee Centre for Character & Virtues; 2020.
44. Kristjansson K, Pollard D. Phronesis: using an Aristotellian model as a research tool. University of Birmingham: The Jubilee Centre for Character & Virtues; 2021.
45. Darnell C, Gulliford L, Kristjánsson K, Paris P. Phronesis and the knowledge-action gap in moral psychology and moral education: a new synthesis? Hum Dev 2019;62:101-129. https://doi.org/10.1159/000496136
46. Guo L, Fang M, Liu L, Chong H, Zeng W, Hu X. The development of disaster preparedness education for public: a scoping review. BMC Public Health 2025;25:645. https://doi.org/10.1186/s12889-025-21664-0
47. Johnson VA, Ronan KR, Johnston DM, Peace R. Improving the impact and implementation of disaster education: programs for children through theory-based evaluation. Risk Anal 2016;36:2120-2135. https://doi.org/10.1111/risa.12545
48. Bencze JL. Building networks for critical and altruistic science education: seeking ubiquitous

social justice and environmental vitality. Springer Nature; 2025.
49. Nolan E, Zeidler D. Transformational learning for complex socioscientific issues. Res Sci Educ 2025;55:771-791. https://doi.org/10.1007/s11165-025-10264-y
50. Zeidler DL, Herman BC. Lessons from history and the human condition: the need for SSI scholarship and instruction. In: Zeidler DL, editor. A moral inquiry into epistemic insights in science education: personal and global perspectives of socioscientific issues. Springer Nature; 2024. p. 427-433.
51. Högström P, Gericke N, Wallin J, Bergman E. Teaching socioscientific issues: a systematic review. Sci Educ 2024:1-44. https://doi.org/10.1007/s11191-024-00542-y
52. Goldman D, Assaraf OBZ, Dawson V, Eilam E, Gokpinar T, Naugauker N, et al. The voice of policymakers, professional development leaders, and teachers who engage in climate change education: a cross-country comparison. In: Cakmakci G, Tasar MF, editors. Connecting science education with cultural heritage. Contributions from Science Education Research, vol 15. Springer; 2025. p. 335-347.
53. Zhang Y. Experiencing human identity at dark tourism sites of natural disasters. Tour Manag 2022;89:104451. https://doi.org/10.1016/j.tourman.2021.104451
54. Sá-Pinto X, Beniermann A, Børsen T, Georgiou M, Jeffries A, Pessoa P, et al. Learning evolution through socioscientific issues. EuroScitizen COST action network. Publishing House of the University of Aveiro (UA Editora); 2022.
55. Duckett SM, Rushton EAC, Löfstedt R. Where is risk education? Exploring risk education in secondary schools in England. J Risk Res 2025;1-19. https://doi.org/10.1080/13669877.2025.2496225
56. Park W. Beyond the 'two cultures' in the teaching of disaster: or how disaster education and science education could benefit each other. Educ Philos Theory 2020;52:1434-1448. https://doi.org/10.1080/00131857.2020.1751126