# Opinion Page: How Science Education helps Learning from Disasters: Grenfell and Sewol

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In recent years, there have been major opportunities and challenges for science educators. On the one hand, the coronavirus pandemic has shed light on the importance of international scientific collaboration in combatting a global public health emergency, creating unrivalled opportunity to teach about the nature of science in the current time. At the same time, and perhaps more importantly, the pandemic has posed pressing questions around science mistrust and denial, policymaking in the absence of conclusive evidence, and delineation between scientific and pseudoscientific claims, which are central concerns to science educators (Osborne et al., 2022).

What has worsened the crisis is its coincidence with post-truth enthusiasm, where appeals to emotion overwhelm facts and reason, indeed where the very possibility of fact and truth is denied. Non-scientific and anti-scientific attitudes can be particularly malicious during a disaster like the pandemic and negatively impact individual and social well-being. As Fortun and Morgan (2015) note, information related to disasters is “almost always contested and politically charged” (p. 61) and therefore easy to be distorted and mislead the public. What is, then, the role of science education in mitigating, coping with, recovering from and remembering disasters? How should science education researchers, policymakers and practitioners act to make change?

## Classroom Opportunities

Some readers might wonder why science, of all subjects, should take on such tasks. Cannot these be left to other subjects like history and social studies?

First, while these school subjects should keep contributing to disaster preparedness and resilience, it does not mean that science is irrelevant or has no role to play. Social studies aim to cultivate democratic citizenship, but that does not preclude science from pursuing the same goal. Recent arguments for teaching about risks in science education (Christensen, 2009; Kolstø. 2006; Schenk et al., 2019) also show that science can play a pivotal role to play in understanding disaster risk. This view resonates with the call for a radical and action-oriented science and technology education by adopting new goals in relation to the contemporary social, ecological and material conditions (Alsop & Bencze, 2014).

Second, there are compelling reasons to see science as genuinely integral to our understanding and response to disasters, and any education about disaster that leaves out its scientific dimension would be incomplete. At the beginning of the pandemic, I drew on the ideas of philosophy of technology to suggest that, by learning about disasters in science education, students can not only gain the knowledge, skills and competences needed for coping with disasters but also develop a deep understanding of how science and technology operate in modern society (Park, 2020). This initial idea has led me to work with disaster scholars, bereaved families, activists, and educators to examine how science education can help us build disaster resilience for social justice.

This essay considers two disaster examples that are technological in nature—a residential building fire and a maritime accident. This choice is intentional, because it is often less evident how technological disasters, compared to disasters like earthquakes, droughts and climate change, can relate to and be addressed in science education. These disasters are nowadays ubiquitous across the world—fires, building and infrastructure collapse, aeroplane crashes, blackouts, toxic wastes, dam failures, nuclear disasters, chemical spills, and factory explosions, just to name a few.

When a technological disaster happens, it is rare to see the disaster's scientific or technical aspects discussed in the media; the absence of science and technology can be similarly noticed in visits to disaster memorials and museums. A possible reason for this is that these disasters are often attributed to *human* failures, having little to do with science or technology. Science and technology studies (STS) scholars have challenged such a view, by pointing to the inherent complexity of some technological systems that make them destined to fail (Perrow, 1984; Pinch, 2012).

Instead of thinking of disasters as a result of human mistakes—it is the systematic failure of a *network* of humans and non-humans that cause a disaster—an STS approach understands them as "failures of diverse, nested systems, producing injurious outcomes that cannot be straightforwardly confined in time or space, nor adequately addressed with standard operating procedures and established modes of thought" (Fortun et al., 2016, p. 1004).

**Disaster investigation as a scientific activity**

In 2022, two important disaster investigations were conducted. These are the focus of this paper (Figure 1). The first case is the sinking of MV Sewol in 2014 near the southwestern shores of South Korea, with 476 people on board. It killed 304 passengers, most of whom were high school students on the way to a field trip to Jeju Island.

The year 2022 also marked the fifth anniversary of the Grenfell Tower fire in North Kensington, London, that happened on the night of 14th June 2017. One of the worst disasters in modern British history, the fire claimed the lives of 72 residents, coming from culturally diverse backgrounds, in the high-rise apartment. Although occurred three years apart and in different parts of the globe, there are strikingly similar aspects of the two disasters, many of which were revealed during the investigations.

Investigation of a disaster is a scientific activity. It uses evidence, either existing or generated, to establish facts, and construct and test theories about what happened during the disaster. As Perrow (1984) observed by analysing the Three Mile Island nuclear accident, a disaster includes a complex chain of errors, failures and interactions that are in need of scientific investigation and analysis. This complex nature of disasters makes them inherently "epistemic events" that involve the (un)production of knowledge (Frickel & Vincent, 2010).

Disaster investigation as a scientific activity should not be equated or conflated with a criminal investigation. It is because, as Jasanoff (1995) emphasised, science and law are similar in their purpose to discover the truth, but there are important differences. Both Grenfell and Sewol investigations were independent of the legal procedures and inquisitorial in nature, focusing on setting out the chain of events leading to the disaster under investigation. As former UK Prime Minister Theresa May said after Grenfell, we undertake investigation because "we need to know what happened, we need to have an explanation of this".

As easy as the task of scientific fact-finding sounds, it is never simple. Scott Gabriel Knowles describes what happens when a scientist enters the disaster scene:

> When scientists and engineers leave the lab and enter the investigative team, they assume a temporary role as arbiters of disputes that have often become (often instantaneously) hopelessly politicised, wielding "facts," and scientific method in the name of rational blame assignation. (Knowles, 2013)

An investigation committee was set up shortly after each disaster to understand what happened and why. Despite the scientific nature of disaster investigation, it was rare to see the technical and scientific aspects of the investigations in media coverage of Grenfell and Sewol. The intimate relationship between science and disasters remains hidden to folk until they see or experience disaster hearings and trials where scientists and engineers produce ample knowledge about what happened and what went wrong. Much of it became only visible after the "black boxes"—complex technological systems whose inner workings are obscured and incomprehensible (Latour, 1999)—were opened, through a long and laborious process of collecting and analysing evidence, piece by piece, by the public inquiry.


**Figure 1.** Reports of the Sewol (left) and Grenfell (right) investigations. (Source: The Special Investigation Commission on Humidifier Disinfectants & 16th April Sewol Ferry Disasters, and Grenfell Tower Inquiry)

**The Grenfell Tower fire (2017)**

The Grenfell Tower Inquiry was established three months after the fire to investigate the disaster in two phases. The first phase of the Inquiry focused on how the blaze started and then rapidly developed. The second phase, conducted between 2020 and 2022, delved into how the tower came to be in a condition that allowed the fire to spread in such a way.

Throughout the four years, the Inquiry was assisted by 17 expert witnesses, the majority of whom were scientists and engineers studying fire safety from different academic backgrounds, including mechanical engineering, aerospace engineering, forensic chemistry. The role of these expert witnesses was to "give an opinion on matters which call for expert skill and knowledge", but perhaps more challenging for them was to communicate their scientific opinions to the members of the Inquiry, not all of whom had a scientific background.

From the early phases of the Inquiry, it became evident that the refurbishment of the building between 2012 and 2016 and the cladding system introduced then were significant contributors to the disaster. The cladding system, attached to the external concrete wall, comprised a layer of insulation and the aluminium composite material (ACM) rainscreen panels, and a cavity separating the two. The combustible polyethylene core of the ACM cladding panels turned out to have allowed the flames and hot gasses to pass, which was identified as the principal reason why the fire spread violently at an unusual speed (Figure 2). The Inquiry ascertained that the fire started in the kitchen of one flat in the tower, escaped the flat through the kitchen windows, and spread throughout the building rapidly such that many people were unable to escape the building.

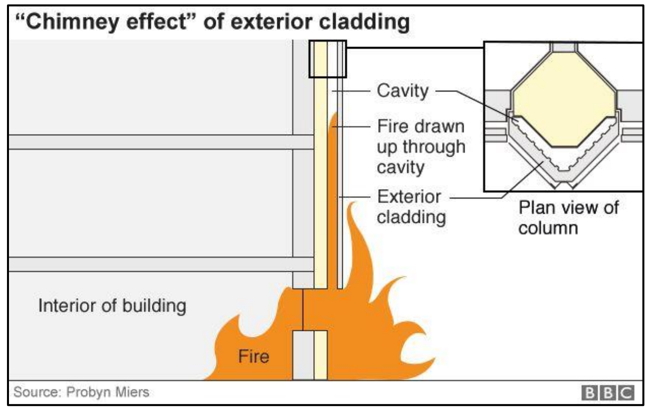


**Figure 2.** Exterior cladding of Grenfell Tower (Source: BBC)

On 9th June, 2022, José Torrero, a fire safety engineer and professor at University College London, provided expert witness evidence relating to the fire safety testing regulations. In order to explain the principles of fire testing, he started with physics knowledge that the velocity of a fluid is proportional to the square root of the pressure potential—or Bernoulli's principle (Figure 3). Understanding this relationship is a prerequisite for determining the key physical parameters controlling the spread of fire, which in turn allows assessing the adequacy of the regulatory regime.

**Figure 3.** Professor and fire safety engineer José Torrero. (Source: Grenfell Tower Inquiry)

During the Inquiry, it was not only the content of science that expert witnesses had to explain to the panel to grasp what happened on the night of the fire. They also had to convince people about the process in which scientific investigation of the fire is carried out. At the hearing on 19 June, 2018, forensic chemist and professor Niamh Nic Daeid at Dundee University began her expert witness presentation by explaining the chemistry of combustion, after which she introduced the process of fire scene investigation (Figure 4). She emphasised that "It is often stated that fire scene investigation should follow what is called a scientific method. This presents a systematic data collection and data analysis process, followed by the development of various hypotheses, which are tested against that data, and a final hypothesis is chosen".

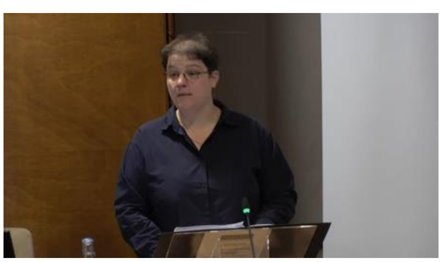

**Figure 4.** Professor and forensic chemist Niamh Nic Daeid. (Source: Grenfell Tower Inquiry)

These two episodes, selected from the many hearings of the Grenfell Inquiry, vividly illustrate that scientific knowledge and methods are indispensable to investigating, and therefore understanding, a disaster. Science is crucial to understanding why a disaster occurred and how, which is a starting point for building resilience and achieving justice. Experiments and tests based on scientific methods and models form the foundations of fire safety and are crucial to identifying the failings involved in disasters, attributing responsibility and blame, and considering how not to repeat the same mistake. As citizens, students should be able to grasp the scientific basis of disasters and the role of science and engineering in our understanding of disasters.

**The Sinking of MV Sewol (2014)**

The Grenfell Tower Inquiry managed to reach a conclusion, with a good level of certainty and agreement, about where the fire started and how it could spread at an unusual rate. Still, they were unable to establish what exactly caused the fire, a relatively minor issue in the overall process of the investigation. The Sewol investigation similarly failed to arrive at a satisfactory conclusion about the rapid turning, heeling, flooding and sinking of the vessel, but this matter was of much greater importance than in Grenfell's case.

Although in separate times and spaces, comparing Sewol with Grenfell exposes stunning similarities between the two disasters. The Sewol Investigation (formally The Special Investigation Commission on Humidifier Disinfectants & 16th April Sewol Ferry Disasters) had an aim similar to that of the Grenfell Tower Inquiry—to set out the events leading to the capsizing and sinking of the ship, and how an accident was made a disaster. Like the refurbishment of Grenfell that led to the use of the cladding products that were violently combustible, the Commission found that MV Sewol had gone through renovations that raised its centre of gravity by 64.2 to 83.2 cm, compromising the vessel's transverse stability (i.e., the ability to recover from heeling and return to vertical; see Figure 5).

The investigation also identified other factors contributing to decreased transverse stability, such as insufficient ballast water and overloaded and poorly fixed cargo (Figure 6). In addition, the Commission found that these conditions were made possible due to cascading human errors and inadequate decisions that gave rise to them, from testing and certification bodies, the captain and crews, the Coast Guard, and the government.

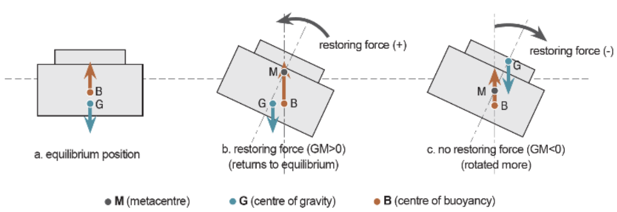


**Figure 5.** The relationship between the centre of gravity, centre of buoyancy, and restoring force. (Source: The Special Investigation Commission on Humidifier Disinfectants & 16th April Sewol Ferry Disasters)

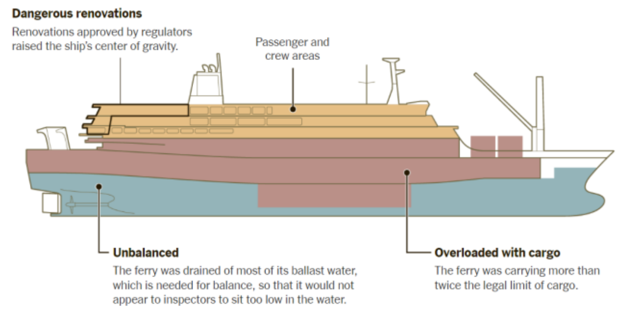


**Figure 6.** Major failures that caused the sinking of MV Sewol. (Source: New York Times)

Like the Sewol Commission, the Grenfell Tower Inquiry collected various existing sources of evidence and also generated fresh evidence by undertaking a programme of experiments in varying physical conditions. Among the core sources of evidence were model simulations and experiments. The Maritime Research Institute Netherlands (MARIN), at the request of the committee, performed tests and simulations using a model ship generated to a scale of 1:25 (Figure 7).

The tests were carried out in the presence of the bereaved families and representatives from the Commission. Based on the available evidence about the ship's tracked positions, cargo movement, and rudder motions, and newly produced experimental evidence, MARIN concluded that the sharp turning, extreme heeling, and subsequent flooding and sinking of the vessel could be fully explained from a hydrodynamic point of view (see Jeon, 2020 for a summary of early MARIN experiments), without introducing any external force that might have been exerted by an underwater object.

Also involved in the investigation was a professional organisation of naval scientists and engineers. The Society of Naval Architects of Korea (SNAK), at the request of the Commission, reviewed the relevant evidence independently, examined the salvaged vessel, and assessed hypotheses about the cause of the disaster. In the opening of the expert witness report, the society establishes the principles for the assessment of hypotheses that are worth noting:

i. When the records are not 100% available about an objective fact, there can exist multiple hypotheses in order to investigate the fact.

ii. The assessment of hypotheses should follow the process of science and engineering investigation, adopting the most probable hypothesis, and rejecting hypotheses that are significantly less likely (p. 4).

SNAK fully endorsed MARIN's conclusions from the experiments about the cause of the accident, but the Commission's final report dissented from their analysis, raising questions about several technical aspects of MARIN's experiments that rejected the possibility of an external force. Instead of providing an answer to what caused MV Sewol to sink, the Commission stated:

… evidence was not sufficient and interpretations were competing. In particular, the material evidence relating to the sinking of MV Sewol was damaged and lost while the vessel was immersed in the water. Due to these constraints, it was difficult for the Commission to identify the cause of the sinking with sufficient evidence and no doubt. (p. 89)

The report recognised that two of the six members present at the meeting—who found the MARIN report scientifically valid and acceptable—expressed a dissenting opinion.

The Commission's divided conclusion can be viewed in a number of ways. Some attribute it to the uncertainty and dispute involved in science-in-the-making, or the lack of evidence sufficient to reach a single conclusion about the sinking. Others may trace it back to the political nature of disaster investigation and how the outcomes might be influenced by partisan politics and polarisation (Chung et al., 2022; Jeon et al., 2022). The Special Act instructed that the Commission should comprise nine members—one recommended by the Chairman of National Assembly, four by the ruling party, and the remaining four by the opposition party. This stands in contrast to the Grenfell Tower Inquiry where all panel members were appointed by the Minister.

Investigation into the Sewol disaster might not have achieved a single conclusion, but the Commission's efforts were not in vain. The investigation has increased our knowledge about various facets of the Sewol disaster, and it has brought to light important issues that had not been noticed previously. The final report describes why the Commission thinks that their activities still have value:

The Commission could conclude that the possibility of an extreme right turn due to a broken solenoid valve is very low and the hypothesis that Sewol sank due to a collision with an underwater object is not supported by evidence. By testing and verifying widespread rumours, the Commission contributed to mitigating unnecessary controversies and reducing social costs. (p. 89)

**Disaster investigation, nature of science, and activist science education**

As underscored by Professor Daeid and SNAK, disaster investigation involves a scientific process of gathering and assessing evidence and formulating and testing hypotheses about why the disaster happened and what went wrong. Disasters such as Grenfell and Sewol, when understood as systematic failures of high-risk technological systems (Perrow, 1984), can be thought of as phenomena to investigate and produce knowledge about, which can in turn inform our future actions. Although disaster investigation is often not perfect and there are remaining uncertainties about the two disasters, it is evident that, compared to 2014 and 2017, we are here with much more evidence, more analysis, and consequently, more knowledge about Sewol and Grenfell.

The shocking failures exposed by the investigations, and the uncanny similarities between the two disasters, should not be forgotten. We need to ask: Who is be held accountable and liable? Who bears the blame? And most importantly, how can we not repeat it? These are important questions pertaining to disaster justice, but let us remember that underlying all these questions is “What happened, and how?”, which is an inherently scientific question. Scientific evidence and inquiry are a necessity—although not always a sufficiency—for ascertaining facts about the material and human world.

Disaster investigation can, retrospectively, reveal the sources of risks and how they interact in unanticipated ways to cause a disaster. Crucial to this task is the exploitation of scientific tools such as data collection, data generation and data analysis, and testing competing hypotheses relating to the cause of the disaster. Any account of a disaster involves humans as well as non-humans—regulations, physical laws, cargo, ballast water, cladding panels, solenoid valves, model ships. Disaster investigations tell us much about the nature of high-risk technological systems, comprising humans and non-humans, that are ubiquitous in society, and the role of science in our efforts to tackle such risks. Such a close relationship between science and disasters points to the potential contributions that science education can make to imagining and building a better society.

Meanwhile, to the extent that disaster investigation is a scientific activity, it becomes subject to the *limits* of science. Both Grenfell and Sewol investigations suggest that it may not always be possible to identify a single, root cause of a disaster—this could happen when the evidence is insufficient and the “theory” is underdetermined by what is available, or when it is not even possible to generate further evidence whilst key evidence was already lost.

Empowering citizens, particularly those who have been historically marginalised, with an understanding of disasters will be the first step to changing the process in which decisions about disasters are made. Rumbach and Németh (2018) remind us that “decisions about who gets what, as well as the mechanisms of re-distribution, are very often left to historically powerful actors rather than the likely beneficiaries of such actions” (p. 343). A scientifically grounded understanding is also fundamental to assigning blame, based on the cause of the disaster identified from investigation. When there is a shared understanding, it will help communities and countries to be better prepared to withstand and bounce back from disasters.

Underpinning the argument about addressing disasters in science education is the idea of activism, defined as “intentional efforts to promote, impede or direct social, political, economic or environmental change" (Alsop & Bencze, 2018, p. 8).

Learning about disasters can open the door to critical reflection on the nature of science and technology in the context of tragedies where science meets politics, ethics, and history, which can lead to action to make society understand and minimise disasters. This way, education for disaster justice and resilience resonate with a radical and action-oriented vision for science and technology education aimed toward social justice.

For us to achieve such an aim, science education needs to support students to grasp, with the help of science and engineering knowledge, what caused a disaster as well as the underlying conditions that make societies vulnerable to disasters in the short and long term—inequality, poverty, corruption, discrimination, urbanisation, and lack of education. We need to remember disasters rather than forget, and science educators should be a key player in shaping how we remember disasters.

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