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This article proposes a competence-based learning framework for science teaching, applied to the study of 'big ideas', in this case to the study of natural hazards and disaster risk reduction (NH&DRR). The framework focuses on new visions of competence, placing emphasis on nurturing connectedness and behavioral actions toward resilience and sustainability. The framework draws together competences familiarly expressed as cognitive knowledge and skills, plus dispositions and adds connectedness and action-related behaviors, and applies this by means of a progression shift associated with NH&DRR from abilities to capabilities. The target is enhanced scientific literacy approached through an education through science focus, amplified through the study of a big idea, promotion of sustained resilience in the face of disaster and the taking of responsibilities for behavioral actions. The framework is applied to a learning progression for each interrelated education dimension, thus serving as a guide for both the development of abilities and as a platform for stimulating student capabilities within instruction and assessment.

Keywords: *Competence; Scientific literacy; Learning progressions; Natural hazards; Disasters; Capabilities; Social resilience; Sustainability*

Introduction

Rapid globalization and advancements in today's world have generated pressures that impact on policies and practices in science education (Fensham, 2011). Among these

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pressures are vulnerabilities of many countries to natural hazards and disasters. This is leading governments to make commitments to reduce the impact of disasters on their citizens through the 'use of knowledge, innovation and education, building a culture of safety and resilience at all levels' (Wisner, 2006).

A more recent science education trend is the inclusion of hazard and risk-related awareness, skills and dispositions within the school curriculum (NRC, 2012; OECD, 2006, 2009; Selby & Kagawa, 2012). This paper puts forward an educational framework applied to natural hazards and disaster risk reduction (NH&DRR), recognizing big ideas (Earth Science Literacy Initiative, 2010) and promoting learning of real-life relevance. It is supported by research indicating that future expertise, in areas such as handling natural hazards, depends on capabilities to ensure that the acquired knowledge is usable, connected and 'conditionalized' within applicable contexts (Bransford, Brown, & Cocking, 2000). Studies show that the superior performance of experts is acquired gradually and achieved through deliberate practice, sustained training and efforts designed sequentially (Ericsson, 2006). However, students are often exposed to a compartmentalized and linear curriculum through acquisition of isolated pieces of sterile knowledge (Stevens, Delgado, & Krajcik, 2010). This suggests that students may not be gaining the knowledge and skills necessary for taking well-informed and appropriate societal actions, and may be in danger of increased vulnerability rather than increased resiliency in the face of adversity. Since experts typically exhibit resilience, have well-connected knowledge structures and engage in deliberate behavioral practices, it is useful to include such attributes in a well-conceived competence framework, encompassing essential elements necessary for expert thinking, feeling and doing. In addition, progression in learning can help students organize their learning by depicting pathways from novice to more sophisticated or expert performances, accelerating student progress toward expert-like capabilities and enhancement of scientific and technological literacy (STL). However, many teachers are unclear how learning for competence development progresses in specific domains (Heritage, 2008). Drawing from these ideas, this paper focuses on depicting a general framework applicable in any science education setting, expressed in terms of competence-based learning; and application of this framework in a teaching context, that is, NH&DRR.

This paper describes such a framework and its application, which is developed by considerations associated with the following three questions:

1. What educational strategies can promote scientific and technologically literate students who can acquire appropriate capabilities to face real-life challenges, seek sustainable solutions to current problems and formulate behavioral actions?
2. How can a broadly applicable competence-based, science learning framework be configured, supporting the development of a meaningful learning progression (LP) across years of schooling?
3. How can the framework be applied to the study of NH&DRR, aiming to promote a safer, action-oriented and resilient community for the future?

Before addressing these questions, four key concepts, identified as educational competence, STL, social resilience and LPs, are outlined.

Educational Competence

Many education curricula in Europe (Arjomand et al., 2013; Eurydice, 2002, 2012), in Australia and New Zealand (Fensham, 2012) and elsewhere in the world embrace the development of competence as the 'capacity' or 'potential' for acting efficiently in a given context (Eurydice, 2002). Competence has importance in situations involving intricate and multi-dimensional problems for which no straightforward approaches to problem-solving are appropriate (Westera, 2001).

While key competences identify broad educational goals (Eurydice, 2012; Rychen & Salganik, 2005), general competences are put forward to include a range of attributes such as critical thinking, creativity, problem-solving and collaboration (Arjomand et al., 2013), plus more subject- and context-oriented components, such as content knowledge, psychosocial resources and behavioral actions (EC, 2006; Rychen & Salganik, 2005). Competence thus encapsulates a complex amalgamation of knowledge, skills or practices, attitudes, values and behaviors that are transversal and interdisciplinary, yet also domain-specific.

Scientific and Technological Literacy

Conceiving competence within science education establishes a close link with perceptions of STL (or scientific literacy) which embrace 'scientific literacy for citizenship' (Dimopolous & Koulaidis, 2003; Kolstø, 2001; Millar, 2006) or 'citizen science' (Jenkins, 1999). STL conceptualizations see lifelong learning and employability attributes being placed alongside intellectual development, personal advancement and social responsibility (Holbrook & Rannikmäe, 2007, 2009). Such views interrelate with a two-vision view by Roberts (2007), where vision I is subject-oriented and vision II focuses on *science-related situations within* society as the context. In terms of subject-orientation, STL encompasses science competences seen in terms of realities, operations and applications, where *science* is seen in an 'education through science' setting (Holbrook & Rannikmäe, 2007), but building on explanations associated with phenomena and conceptual learning through linking theory with practice. While science can be sub-divided into components such as biology, chemistry, earth science and physics, all embrace the gaining of relevant knowledge and operational skills leading to reasoned problem-solving and decision-making in meaningful contexts. Although decisions within STL are science-dependent, other perspectives such as economics, ethical and environmental concerns are also integrated into the argumentation process (Holbrook & Rannikmäe, 2009; Millar, 2006; Roberts, 2007; Sadler & Zeidler, 2009). Choi, Lee, Shin, Kim, and Krajcik (2011) point out metacognition and self-direction as other important elements of STL.

From these perspectives, STL is seen as all-encompassing, covering interdisciplinary science knowledge and skills, including STEM (integrated science, technology, engineering, mathematics) practices and dispositions related to functioning in real-world contexts, and as such lays the foundation for a science learning framework.

Social Resilience

Possessing social resilience enables individuals to adapt and re-bound in the face of challenging social environments (Ecclestone & Lewis, 2014; Fazey et al., 2007). Social resilience covers the complex demands of school and work, economic competition, natural and man-made hazards besides other crises. In general, social resilience can be viewed as embodying cognitive skills, practices, dispositions and behaviors, which make it a relevant and practical educational goal and a further component of STL. It can be described as a multi-dimensional concept consisting of:

(1) Personal attributes such as the dynamic characteristics of individuals, community practices (Paton & Johnston, 2001), subject independent, and cross-functional capacities (Ecclestone & Lewis, 2014; Hanson & Kim, 2007; Norris, Stevens, Pfefferbaum, Wyche, & Pfefferbaum, 2008; Paton & Johnston, 2001).
(2) Social attributes, viewed as the adaptive capacities of ecological and social systems to reorganize and renew themselves in the face of change, and are therefore an integral element of sustainable development (Ecclestone & Lewis, 2014).

Learning Progressions

A competence-learning framework includes not only a selection of core content, but also a pathway learners can follow to reach meaningful levels of scientific literacy, enabling them to participate within science lessons and real-world situations. A LP is an approach that maps out science concepts, practices and dispositions across multiple points leading toward a wider and more sophisticated promotion of scientific literacy (Hess, 2010; NRC, 2007; Stevens et al., 2010). An LP reflects movement toward increased understanding and practices (Hess, 2010) that traverse from a lower anchor—students' prior knowledge and skills that lack sophistication, to reach a higher complexity upper anchor—societal expectations about students' capabilities when they complete a defined grade band or progression (Hess, 2010; NRC, 2007). Associated with this is the growth of meaningful personal and social dispositions illustrating functioning as ethical and capable citizens within the society.

A Competence-Based Science Learning Framework

This paper offers the following set of enhanced competence indicators within a meaningful framework aimed at adequately preparing students to enhance their scientific literacy, and thus become competent and resilient in the face of real-life challenges. An important feature is the intention to go beyond the development of scientific and cross-functional abilities and pay particular attention to the development of capabilities. While abilities are defined as being able to do, based on specific learning or in a routine/familiar situation, capabilities are taken to indicate the 'potential' to act effectively and efficiently, even though the situation may be unique or of a non-routine nature. Capability reflects competence, interconnecting subject, personal and social knowledge, skills and values applied to an unfamiliar environment.

The competence indicators (Figure 1) build on a learning platform within a subject orientation, encompassing content knowledge, skills and dispositions (attitudes and values) (Eurydice, 2002; Rychen & Salganik, 2005). The indicators promote both the development of abilities and the stimulation of capabilities. Skills in this context are taken to be cross-functional, having a subject and generic nature and interrelating with student cognition. Generic skills attributes are expressed as—adaptability, non-routine problem-solving, complex communication skills, self-development and systems thinking (NRC, 2010).

A further component is connectedness, providing contextual linkages interrelating cognitive knowledge, cross-functional skills and values at personal, societal and global levels. While given less attention in the literature (one notable exception being the New Zealand framework on education for sustainability – Arthur, 2011; Eames, 2010; Eames, Barker, Wilson-Hill, & Law, 2010), connectedness is an essential dimension to enable systems thinking and a focus on education for sustainable development (UNESCO, 2012).

The framework is completed by building on the connectedness learning to give functionality, thus focusing on behavioral actions. For this, both resilience and sustainability are important considerations as students transfer their 'within school' learning to societal reality at local, national or global levels. While knowledge, cross-functional skills and dispositions inevitably form the base, connectedness enables all to lead to context-related behavioral actions, where the context may be subject-embedded, or more importantly, embedded in the society (at local, national or global levels).

These competence indicators can be used to compare current views with an expanded view, introducing wider capabilities. This is shown in Table 1, drawing attention to motivational aspects, especially personal relevance and seeing content

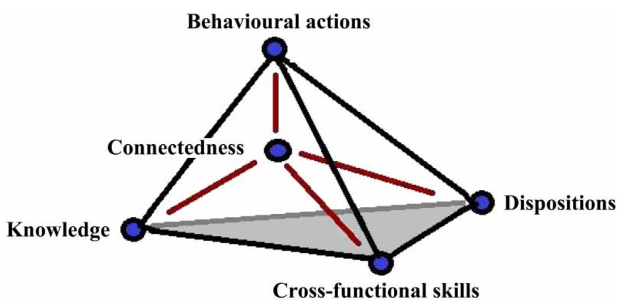

Figure 1. Five competence indicators (baseline competence indicated by the shaded area)

Table 1. Expanded view of indicators for a competence-based framework

	Current views	Expanded views
1. Content Knowledge	1 Scientific knowledge is traditionally presented as a list of topics/ themes with little attention to building crosslinks (Choi et al., 2011; NRC, 2007) 2 Learners possess relevant knowledge and manipulative skills, but are often not well organized and impractical when faced with new problems or ideas (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010; Stevens et al., 2010) 3 Poor student motivation, because of irrelevance and difficulty of science content (European Commission, 2007)	1 Big ideas provide a coherent way of organizing learning to build understanding and practices (Choi et al., 2011; Hess, 2010; NRC, 2012; Stevens et al., 2010) 2 Expert knowledge and problem-solving are organized around 'big ideas' that guide thinking (Bransford, Brown, & Cocking, 2000) 3 The motivational aspect of relevance (Holbrook & Rannikmäe, 2014), especially with respect to students, is a vital consideration alongside situational and personal interest (Krapp & Prenzel, 2011) 4 Students' robust, accurate and activated prior knowledge provides strong foundations for building new knowledge (Ambrose et al., 2010) 5 LP enacted from a variety of perspectives, not just subject content (NRC, 2012)
2. Cross-functional Skills	1 Cognitive skills applicable across subject domains, careers and throughout a lifetime (Ruiz-Primo, 2009) 2 Problem-solving seen as a routine function, with prescriptive experimentation (Tytler, 2007) 3 Decision-making restricted to accepted disciplinary structures (Tytler, 2007) 4 The nature of science seen from a positivist perspective, taking textbook explanations as the truth and observations as objective (Stevens et al., 2010; Tytler, 2007)	1 Skills include futures thinking and risk-based decision-making (Eiser et al., 2012). Futures thinking balance environmental, social and economic considerations with sustainability and improved quality of life through predicting problems and the abilities to think ahead, to forecast and be aware of the future consequences of decisions and actions (UNESCO, 2012) 2 Risk-based decision making based on the anticipated costs and benefits of different decision outcomes (Eiser et al., 2012), requiring proper integration between emotion and reason (Slovic, Finucane, Peters, & MacGregor, 2004) 3 Key elements include non-routine problem-solving, systems thinking and complex communication (NRC, 2010) 4 Creativity and innovation to encompass engineering (NRC, 2012; P21, 2008) through creation techniques (e.g. brainstorming); applying iterative design processes to reach practical and sustainable solutions, while considering human limitations and societal values (Griffin, McGaw & Care, 2012) 5 Systems thinking viewing problems as part of an overall system (UNESCO, 2012); analyzing and judging based on interactions among parts of the system (Choi et al., 2011; NRC, 2010) 6 Complex communication involving capacities to manage and interpret verbal and non-verbal information in taking appropriate actions (Griffin et al., 2012; NRC, 2010); communicate experiences and feelings through arts, IT, oral or written formats (UNICEF Canada, 2010)

3. Dispositions	1 Dispositions include interest and sense of responsibility (OECD, 2006) 2 Students' attitudes, for example, toward natural and learning environments are linked to three key components a *sensitivity*, consisting of empathy (Hollweg et al., 2011) b *self-efficacy or locus of control*, a belief about personal capability to act (Paton, 2003) or the feeling of acceptance toward personal responsibility (Hollweg et al., 2011) c *intention to act* as 'positive attitudes; indications of actions to prevent future problems or solve current issues' (Hollweg et al., 2011)	1 Dispositions additionally relate to adaptability and flexibility, leadership and responsibility, and initiative and self-direction (P21, 2008) 2 *Adaptability and flexibility*, characterized by learners' abilities to consider alternative explanations and points of view; use prior knowledge; engage in effortful thinking and scientific argumentation (Anderman, Sinatra, & Gray, 2012); cope willingly with uncertainty and rapidly changing conditions … , and learn new technologies and procedures (NRC, 2010) 3 *Leadership and responsibility* associated with capacities to guide and lead others by leveraging strengths of others to accomplish a common goal; inspire others; demonstrate integrity and ethical behavior in using influence and power (Griffin et al., 2012) 4 *Responsibility* showing equity, respect for nature, universal human rights and mutual understanding (UNESCO, 2012) 5 *Initiative and self-direction* encouraging lifelong learning (P21, 2008; UNESCO, 2012), autonomous actions (Rychen & Salganik, 2005), and initiatives to advance toward expert skill levels 6 Self-directed learners, able to self-evaluate knowledge and skills, plan approaches, monitor progress and adjust strategies as needed (Ambrose et al., 2010)
4. Connectedness	1 Compartmentalization of conceptual knowledge into disciplinary strands rather than inter-disciplinarily interwoven (Tytler, 2007) 2 Links between people inherent in science practice (P21, 2008) working with others to solve personal, community and global problems (Choi et al., 2011)	1 Connectedness is broadened to include linking thinking, feeling and acting (Arthur, 2011; Coyle, 2005; Eames et al., 2010; Hollweg et al., 2011; McBeth & Volk, 2009; Schultz, 2002) 2 Connectedness encompassing technology and engineering (NRC, 2012). 3 Resilience and sustainability seen as a function of individuals' abilities and capabilities to connect their content knowledge, personal/social skills and attitudes/values (Ernst & Theimer, 2011; UNESCO, 2012)
5. Behavioral Actions	1 Competence is behaving like a scientist with emphasis on procedure, interpretation and technique (Tytler, 2007) 2 Competence viewed as an ability, involved with intentions becoming habitual behaviors, for example, turning off lights when leaving a room (Hollweg et al., 2011) 3 Involve cognitive and affective skills (Coyle, 2005; Hollweg et al., 2011; Jensen & Schnack, 2006)	1 C*itizenship* education—students participate in activities contributing positively to the local/global world; show solidarity (interested in and willing to volunteer, make donations in order to ease suffering) (Griffin et al., 2012); contribute to relief and recovery (UNICEF Canada, 2010); make sense of local, national and global events and trends and participate safely, intelligently, productively and responsibly (P21, 2008) 2 Promotes citizenship competence—foster ability to perform obligations/responsibilities and capabilities to act as citizens at local/national/global levels; facilitate social cohesion, resilience and sustainability (EC, 2006; UNESCO, 2012)

knowledge promoted through big ideas. Cross-functional skills are given more attention and expanded to include an emphasis on twenty-first century skills (P21, 2008), with dispositions, especially values, heavily stressed. Both connectedness and behavioral actions are highlighted, supported by the interplay between emotion and reason.

Applying the New Competence Framework to the Study of NH&DRR

This section discusses the utilization of the five identified competence indicators (Figure 1 and Table 1), when applied to the NH&DRR context. It proposes an ability-capability progression from a lower to upper anchor, applicable across years of schooling (see Appendices 1–6). Within the scope of this paper, the term 'natural' is used to refer to hazards and disasters which are the results of meteorological, geophysical or hydrological processes beyond human control, for example, earthquakes, volcanic eruptions, tsunamis, hurricanes, typhoons and cyclones, lightning, flooding and landslides, and ice and snowfall. However, the theoretical approach developed within these contexts can meaningfully be extended to cover other perils relating to pandemics, industrial hazards or willful hazards (e.g. terrorism, war), etc.

The anchors reflect the characteristics of novices (lower anchor) and experts (higher anchor). The former includes disconnected knowledge and abilities, whereas the latter enables highly connected knowledge so as to allow superior performances, in terms of both anticipation and in capabilities to act (Bransford, Brown, & Cocking, 2000; Ericsson, 2006). The framework recognizes that a study of NH&DRR is not only related to those prone to suffer because of location, but also to those, who in this age of global travel, may become exposed to such natural hazards in the future. As such, the natural hazards are approached holistically and capabilities for behavioral actions promoted in unknown or inexperienced situations.

Competence Indicator 1: Content knowledge applied to NH&DRR

Since the development of knowledge is organized around core concepts or 'big ideas' (Bransford, Brown, & Cocking, 2000; Choi et al., 2011), three components of the big idea – NH&DRR – are identified:

(a) *The science behind natural hazards.*
(b) *The impacts of natural hazards and disasters.*
(c) *Preparedness for disaster risk reduction.*

(a) The science behind natural hazards is an important learning component and includes a range of scientific concepts related to the 'big idea'. Taking NH&DRR as the 'big idea' leads to a range of science learning components, such as those illustrated in Table 2, each related to a specific natural hazard, or hazards. Clearly each science topic can be taken as a big idea in its own right and progression taking place with more developed conceptual demands from the lower to upper anchor, but in promoting a context-based science teaching approach, natural hazards provide meaningful contexts at one or more progression levels relevant to specified natural hazards.

Although Table 2 is expressed in terms of science topics associated with specific natural hazards, its connectedness has outreach into science technology, engineering and mathematics (STEM) learning. While technology and mathematics are expected to interrelate with the detection and measurement of natural hazards, the learning associated with engineering, and especially engineering design, allows the exploration of human solutions to forestall or facilitate risk reduction efforts.

In this component, the LP (see Appendix 1) begins with learners recognizing the changes in their local/national environment, resulting from the Earth's natural processes (e.g. defoliation of forest canopies, or reshaping of coastal landscape due to storm/hurricane/typhoon; high ground becoming flat/steep, or rivers becoming narrow, shallow as a result of landslides). This may be gained via interviews with parents or old people in the community, pictorial activity, film viewing or field trips. Then, learners interrelated this with relevant science phenomena, as outlined in Table 2, to develop scientific explanations at a conceptual level related to the curriculum. This is consistent with suggestions by others (Holbrook & Rannikmäe, 2007; Roberts, 2007). Further, learners increase their grasp of the Earth's processes as they illustrate cause and effect and derive whether they are considering a hazard or a disaster. The ultimate target is for learners to be able to construct and/or use models of the different types of hazards affecting a community/country and offer explanations based on their science learning. This is relevant as learners can be messengers of hazard awareness raising and disaster management able to educate their family/community and critique or challenge worldviews (scientific facts versus beliefs) that may pose threats on social cohesion, safety and resilience.

(b) Developing learners' abilities for *hazard and disaster impacts* (elaborated in Appendix 2) covers, at the lower anchor, identifying impact gains and losses. On the one hand, this implies that learners develop their understanding of natural hazards' devastations, such as loss of life and properties, damage to vegetation and infrastructure/buildings. However, on the other hand, it implies learners appreciate the positive impacts (e.g. spectacular landscapes, abundance of water supply, growth of vegetation and the like); it can lead to stories of social interactions such as socio-scientific decision-making (e.g. acts of bravery, generosity and kindness of ordinary people, community rebuilding). Furthermore, focusing on both aspects promotes a culture of scientific safety, socio-scientific empathy and engineering or technological citizenship skills (UNICEF Canada, 2010), as well as cultivating aesthetic appreciation of the complex relationship between natural forces and technological advances.

Such learning targets facilitate progress toward reaching the upper anchor, identified as fostering capabilities to utilize STEM learning in problem-solving or decision-making when handling real or simulated impacts from hazards and disasters on local/global communities, supported by local

Table 2. Examples of science learning to be developed alongside, or associated with, the cited natural hazard through the LP

	Volcano	Storm hurricane/ typhoon	Lightning	Landslide flood	Earthquake	Tsunami
Matter, change of state	x					
Heat transfer	x		x			
Air, air movement and breathing	x	x	x			
Soil, erosion	x			x	x	
Force (energy)	x	x		x	x	x
Earth, plate tectonics	x				x	
Pressure		x				x
Water, solubility, buoyancy, currents		x		x		x
Static electricity			x			
Vegetation		x		x		

experiences. Capabilities to put forward multi-faceted STEM-related plans for the revitalization of disaster-stricken communities, taking into consideration socio-scientific decision-making involving both social cohesion and sustainable development, are also upper anchor targets. Teaching suggestions may include projects which can also include working with their parents and other members in the community in simulating clean-up drives, recycling operations or conservation of resources.

(c) The progression within the scope of *disaster preparedness*, as illustrated in Appendix 3, shows the learning pathway covering adaptation strategies directed toward the development of individual/group capacities and an analysis of the role of technology and engineering in facilitating or undertaking design and construct activities, stemming from a science learning base which deals with major challenges in risk reduction. The latter is seen as crucial in today's technological world, where technological knowledge, linked to an awareness of nature and the impact of hazards, provides a strong base for developing capabilities associated with NH&DRR (NRC, 2012). The lower anchor is directed at developing learners' ability to accept the inevitability of natural hazards and therefore be able to explain and demonstrate common precautionary measures such as drop, cover and hold (earthquake); life jacket use/swimming (flood/tsunami); stop, drop and roll (fire); light search, first-aid; and removal of hazardous materials and utility shut-off. It also includes the ability to identify technology and engineering practices used in detecting and mitigating adverse effects of natural hazards; and explain scientific principles and technological laws used in determining safety standards and structural designs (AAAS, 2001). Within this level, a DRR speakers or others can be invited to conduct drills or training to master proper behavior before/during and after a hazard strike. Also, engineers, architects and others can be invited to discuss design features (e.g. size, shape, weight) and properties of materials (e.g. strength, hardness and flexibility) that can protect the community from natural hazards. Case studies (e.g. Japan's engineered solutions to earthquake) are also effective in elucidating design techniques that make buildings sway rather than collapse during an earthquake. At the upper anchor, learners develop the capability to create preparedness plans at the family, school or community levels in unknown situations, making use of STEM learning. For instance producing a preparation checklist, family contact and reunification procedures, supplies kit, coloring/activity books for young children featuring proper behaviors should a hazard hit, evacuation routes/safety map and so on. Further, learners' capability to design and engage in iterative processes of testing, evaluating and refining engineering creations can be developed. This can be by having learners undertake collaborative STEM problem-solving research work and using simulations or constructing models or equipment (e.g. wind resistant roof/wall, flood-resilient bridge, rainwater drainage channels, weather instruments), testing their effectiveness and modifying them in order to propose the most sustainable solutions.

Competence indicator 2: Cross-functional skills development through studying NH&DRR

Many opportunities for learning cross-functional skills are important for enabling support for both creative approaches to investigate natural hazards and the capability of putting forward innovative ways to reduce disaster risks (Appendix 4). The initial platform is to recognize that science and technology are creative endeavors and operate together in creative developments, involving engineering practices such as designing, building, testing and eventually evaluating (NRC, 2012; P21, 2008). Within this indicator, learners can be exposed to viewing films, pictorial analysis, internet search or interviews with engineers, architects or others to help them recognize how community resources—building, infrastructure, practices—are evolving over time as a result of continuous effort to innovate and be creative so as to increase safety. Also, learners can develop self-determination and education through science attributes (Holbrook & Rannikmäe, 2007) such as collaborative skills and communication skills encompassing argumentation skills. This can lead to constructing arguments on how existing engineering solutions or practices in a specific location can be better designed or implemented to raise local or national safety and resilience against hazards and disasters. Through progression, learners can reach the intended target of the upper anchor. This can be done by engaging students in the enhancement of scientific literacy through appreciating the nature of STEM endeavors, personal development and also social attributes so as to be creative and undertake collaborative, innovative activities, such as model construction or drawing that allow learners to devise or design novel products or processes applicable to a real or hypothetical community. Students can be expected to defend their position with strong argumentation and illustrate how their actions and products can be shown to reduce adverse impacts from frequent to occasional, specifically identified, natural hazards. Moreover, learners can incorporate acquired skills related to computer simulation to test the effectiveness of their design under different operating conditions, noting how the simulation may be limited in accurately modeling the real world. They can also acquire capabilities to test what happens if parameters of their model are changed, taking into consideration the identified constraints, reliability and safety aspects, scientific conceptual learning and societal values (AAAS, 2001).

The capability for futures thinking is seen as a major target. As shown in the lower anchor (Appendix 4), the ability to cope with the concept of time is essential and forms a major factor in developing the ability to create a futuristic vision (Jensen & Schnack, 2006). This can mean utilizing learners' imaginations to create their own version of a better town/city or community through models, drawings, simulations, role playing or sketches showcasing futuristic structures or practices that could better respond to unknown and much stronger natural disasters. It can be extended to engage learners to socio-scientific debates or public presentations to convey their imaginary futures and suggest, based on well-reasoned scientific and engineering principles, preferable future directions through meaningfully predicting possible problems, thinking of a range of alternative solutions and creatively planning for desirable action should such a disaster occur (UNESCO, 2012).

Risk-based decision-making is another recognized priority (Eiser et al., 2012). It is crucial that students are aware that risks associated with natural hazards are not dependent on the hazard itself but also on the physical and social conditions. Also important is to identify other variables, such as risk interpretations, judgment or the decision-making process (Eiser et al., 2012). It is therefore suggested as vital for learners to develop risk assessment/analysis techniques and develop 'logic, reasoning and scientific deliberations for hazard management' (Slovic et al., 2004).

At the lower anchor (Appendix 4), learners develop the ability to identify perceived risks (e.g. likelihood of a hazard and value/magnitude of any consequences) and the benefits of an action, or solution (Eiser et al., 2012) related to, on the one hand, personal, family and/or community well-being and, on the other, to peoples' livelihood and properties. Within this level, learners can be exposed to hazard hunts, hazard mapping or vulnerability assessment of their school, home or community in order to analyze pre-existing conditions. These conditions may include actually living within a hazard zone, or in poor hazard-resistant building structures or pinpointing people's activities such as illegal mining, quarrying, logging or garbage disposal in drainage or waterways that could put people more at risk of compound hazards. Learners can also engage in role playing or watching films that highlight multiple actions, which can either elevate or decrease safety. This can facilitate easy movement to the upper anchor, enabling learners to indicate capabilities to balance risk and need and thus discuss or debate how people consider risk in their decision-making. In this way learners can foster their development of capabilities that consider a range of social perspectives, associated with the relevant science knowledge and skills, and use argumentation skills to undertake well-reasoned decision-making in unfamiliar situations (Dimopolous & Koulaidis, 2003; Jenkins, 1999; Kolstø, 2001; Roberts, 2007). The goal, however, is to go further and develop the capability to persuade others to support such a stand and propose meaningful and well-supported actions (Jenkins, 1999). For example, learners can make an appeal through letters, poster campaigns or street theatre to encourage local officials and others to improve pre- and post-impact interventions or stop illegal actions (e.g. logging, quarrying) that could put the community in danger.

Competence Indicator 3: Development of dispositions through studying NH&DRR

Societies can expect to face more and more complex concerns in the future, related to nature concerns, health issues and other serious threats. This means there is a proposed need to foster competence in ways that encourage *adaptability and flexibility, leadership and responsibility, and initiative and self-direction* within the study of NH&DRR (Appendix 5).

A common trait associated with experts is *adaptability and flexibility*. Experts are able to approach new situations flexibly, being metacognitive and continually questioning their current levels of expertise and attempting to adapt and move beyond them (Bransford, Brown, & Cocking, 2000). The implication is that learners' experiences should not simply nurture excellence on routine behaviors (e.g. precautionary, safety and self-protection measures). To be able to cope with complex situations, learners' experiences need to cultivate the capability to create meaningful change in a situation (Ruiz-Primo, 2009) by reflecting on the situation and putting forward ideas for improving current, but unknown, practices. It also implies aligning behaviors with external conditions, such as dealing with the impacts of change, for example, rebuilding houses away from flood plains in response to flooding (Fazey et al., 2007).

A starting point is cultivating the ability to be aware that adaptability requires a willingness to weigh and consider diverse views and beliefs (Bransford, Brown, & Cocking, 2000). This also includes the development of abilities to be flexible and open-minded when dealing with the viewpoints of others; or remaining composed and maintaining emotional control when faced with uncertainties (Ruiz-Primo, 2009), such as those which can be due to unexpected experiences or unpredictable reactions. The learning end-point is the development of capabilities to adjust behaviors, plans or goals to deal with unknown, but changing, situations. Several approaches can foster this skill, such as film viewing or online searches that feature heroic or commendable actions of children or people during crises. Other strategies include interviews with a DRR speaker or local community members on past hazard or disaster memories. With these learning experiences, learners are able to identify actions or characteristics that enable people to endure incredible stress or devastation and compare them with those who are less resilient. These in turn can enable learners to put forward suggestions or actions through drama or street theatre, and interactive multi-media presentations, featuring various ways people could adapt to new conditions after a hazard strikes.

Leadership and a sense of responsibility are important pursuits in the face of personal safety and in ensuring the safety of others. Self-responsibility, as a component within self-development, includes students participating actively in all aspects of disaster preparation, mitigation and recovery efforts. At the lower anchor, learners develop a sense of responsibility, which can be applied to help protect themselves, peers, family and the community from NH&DRR. Clearly developing leadership skills, such as persuading or inspiring others to take necessary actions to solve problems, is part of the continuum toward developing a capability to act responsibly in unknown situations by showing equity, respect for nature, universal human rights and mutual understanding. The target is the development of capabilities to recognize and uphold a 'responsibility of distance' to those living afar who are beset with threats of disasters (Selby & Kagawa, 2012), plus showing willingness to maintain a personal commitment to change or toward avoiding behaviors that produce negative impacts. Such increase in learners' responsibilities is crucial; studies reveal that people tend to transfer personal safety responsibility to those who provide the hazard and preparedness information (e.g. local governments, emergency management agencies), which unfortunately, in turn, reduces the likelihood of attending to risk messages and adoption of recommendations (Paton, 2003; Paton & Johnston, 2001). Some approaches seen to foster this skill are group work, role playing, student–community partnerships and project work, in which learners take the lead or have specific roles in disaster preparedness. For instance, learners can lead their colleagues to safe areas/proper behavior, whether this is related to experimentation in the school laboratory, or creating their own household emergency preparedness, which they can share with their family members, including their neighbors and friends.

Initiative and self-direction are further key educational attributes. At the lower anchor, the emphasis is on developing the ability to identify major natural hazards (locally and globally); showing self-initiative to collaboratively work with others to determine possible problems and conducting valid investigations to seek reliable solutions. This can extend to considerations of problem-solving through science and engineering solutions, undertaken to mitigate against hazard impacts. At the upper anchor, developing the capability to reflect critically on histories of past hazards or disasters, enabling the formulation of future, scientific reasoned, risk reduction actions, is of major importance. *Initiative and self-direction* are also seen as important in the development of learners' abilities to learn further about the forces of nature after they leave school (UNESCO, 2012) and work collaboratively to conduct investigations to solve problems and discuss or design engineering oriented risk-mitigating plans. Such development is needed for learners to reach the upper anchor of undertaking self-directed, sustainable and informed actions, including advance actions on precautionary measures. For these purposes, learners can undertake individual or collaborative research project, through which they pursue inquiry or problem-solving in their own way initiated by their own problem-solving question on natural hazards of personal interest. The output can manifest itself in expert-like behaviors during hazard drills; sustainable lifestyles (e.g. throwing garbage in proper places or recycling and conservation of resources); and commitment to continuously search for novel ideas or practices that will elevate family, school or community resilience.

Competence Indicator 4: Connectedness through the study of NH&DRR

The interplay between an individual's knowledge, skills, attitudes/values and behaviors is seen as determining an individual's, or community's, resilience to NH&DRR. This is supported by the notion that an individual's rational behavior is influenced by the complex interplay between emotion and reason (Slovic et al., 2004). Thus, for example, an individual's decision to evacuate is influenced by their understanding of the scientific and technological dynamics of hazards, perceived risks, attitudes and beliefs toward leaving their homes, evacuation center, including their ability to stay safe, etc. This may be ascertained by their own judgment, or by the persuasion of others. Such linkage is described in the progression in Appendix 6, with a starting point of learners' awareness of the need and their ability to handle challenging situations. This leads, by progression, to learners' capabilities to reflect on this relationship and make judgments on how challenging situations affect hazard/disaster preparedness. A key end-point is reviewing current practices from a scientific perspective and enacting improvements and putting forward futuristic actions.

Clearly developing an ability to recognize links between competence indicators is a crucial educational expectation, which can be meaningfully supported through developing abilities to deal with NH&DRR. The upper target is proposed as developing the capability to reflect critically on connections put forward in sources of information (books, printed materials, internet, etc.), historical happenings, communication channels and between interactions geared to people's thinking, attitudes/values, and hence action and hazard/disaster preparedness. The target is to develop the capability to employ strategic socio-scientific thinking processes, so as to analyze connections for improving practices in familiar and unknown situations and especially related to future behavioral actions. Suggested teaching strategies are issue analysis techniques, storytelling, simulations and film viewing that expose learners to actual scenarios enabling them to reflect on how the interconnectedness among knowledge, skills, attitudes/values and behaviors of people affect community resilience to NH and sustainability. Subsequently, learners can create scripts or pamphlets highlighting effective and efficient communications and actions of people at varying ages that will boost resilience, sustainability and social cohesion.

Competence Indicator 5: Behavioral actions toward resilience and sustainability through studying NH&DRR

Disaster situations are complex and, in some cases, can lead to a breakdown of social norms. Depending upon a community's level of resilience, the likelihood of anti-social behaviors, such as hoarding and looting may arise, which can be expected to debilitate a community's capability to respond, recover and rebuild. As such, there is a need to promote citizenship responsibilities that encourage active involvement in contributing positively to the community. This may be by a willingness to volunteer or contribute to relief and recovery for easing suffering (Griffin et al., 2012; UNICEF Canada, 2010). Learners need to be aware of local values and practices, chaos factors and instability concerns in a disaster-stricken community. This can be a start to enabling effective negotiations on key issues and cooperation for actions to rebuild the community.

Beginning at the lower anchor (Appendix 6), an important development is the ability to recognize that citizens have obligations to participate actively, productively and responsibly in community activities based on sound scientific principles. This is to promote, in learners, a sense of social cohesion, resilience and sustainability, whether in local communities, or at the national or global level. Actions, which can be developed in the science classroom, include self-determination in scientific problem-solving or in reasoned decision-making such as, in a real-world sense, donating or volunteering for organizational working in a real or hypothetical emergency zone.

To further aid the cultivation of learners' abilities to expand their citizenship actions, opportunities need to be provided for learners to take an active part in programs that support humanitarian aid and ensure that actions are responsive and respectful of local beliefs and practices. Included in the upper anchor is the capability to take perceived practical and sustainable actions, based on sound scientific principles, not only to cope meaningfully and efficiently with the situation whenever a disaster occurs, but to be prepared to put forward ideas and plans for improving disaster preparedness and ways to speed up aid delivery.

One final important consideration, which is relevant in all five competence indicators, is the recognition of learners' prior knowledge and worldviews about hazards and disasters. Any individual's prior knowledge consists of an amalgam of facts, concepts, models, perceptions, beliefs, values and attitudes that may be accurate or inaccurate, complete or insufficient and appropriate or inappropriate for the context (Ambrose et al., 2010). Studies have shown that incorporating prior knowledge, especially conceptually sound scientific principles, is important as this influences ways of interpreting natural phenomena and imposes an effect on development in enhancing scientific literacy (Tsai, 2001) in order to attain resilience and sustainability. Therefore, teaching strategies associated with each competence indicator need ideally to include assessments of prior knowledge with corresponding adjustments of content and activities as needed.

Conclusion

The proposed framework builds on current views (Table 1) to allow an expanded view of science education, within a more relevant society context, to encompass capabilities refocusing education away from being a body of knowledge and incorporate skills and further capabilities toward responsible citizenship and entrepreneurship. As such, society resilience and sustainability can be promoted.

Contrasting current views with an expanded view place the focus on wider capabilities. For example, content knowledge is interconnected through big ideas; cross-functional skills are extended to include aspects such as creativity and innovation, futures thinking and risk-based decision-making. Dispositions are widened to embrace adaptability, leadership, initiative and responsibility. Connectedness is broadened to emphasize connections between thinking, feeling and acting, characterizing a unique way of looking at the human–nature relationship, incorporating actions and experiences. Behavioral actions extend to responsible citizenship, as manifested in obligations and responsibilities as citizens at the local, national and global levels, thus promoting social cohesion, resilience and sustainability.

The framework, based on the five competence indicators, is applied to NH&DRR as an example of a progression which leads to the development of capabilities focusing on self-development with respect to action behaviors and resilience. This is intended to promote the development of a better informed and more focused population for the future and the realization of appropriate community action.

Limitations

The following limitations are noted in applying the framework to big ideas such as NH&DRR:

1. Culture is not articulated. However, we cannot imagine a society or culture without being exposed to disasters or hazards. As Norris et al. (2008) argue, the difficulty is to find a human culture or society whose disaster readiness is not enhanced by reducing risk and resource inequities, developing individual and collective adaptive capacities, engaging local people, creating linkages, boosting supports and careful planning. As such, it is difficult to envisage that the competence indicators outlined here are irrelevant or inapplicable to any particular, or entire, culture.
2. Although our description of resilience reflects the competence indicators, we do not wish to ignore the complexity and gravity of hazards. No community is always resilient; even the most competent individuals or communities may struggle tremendously to recover (Norris et al., 2008). But this need not bar us from designing teaching and learning approaches that can help students develop the essential knowledge, skills or practices, dispositions and actions needed to become resilient individuals.
3. There are challenges in designing assessment approaches capable of measuring and monitoring the learning suggested through the development of competences. This is seen as a future development.

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Appendix 1

LPs for the science behind NH&DRR

Lower anchor			Upper anchor
Ability to identify/describe observations, information/personal experiences of Earth's natural forces changing the environment, especially for weather/water	Ability to explain characteristics of natural processes; identify/discuss how they become hazards/disasters. Associate patterns; cause/effect (including use of graphs) with weather/climate	Ability to link conditions/factors (mapping, including historical events) influencing different types/ patterns of phenomena/events before hazards occur, including other hazards (e.g. tsunami, landslide) in connection with natural forces	Capability to construct/use models determining likelihood of hazards; predict future risk exposure and safety Capability to obtain empirical evidence to support/refute claims about influence of human activities on increased frequency/intensity of natural hazards (e.g. flood, drought, storm).
Weather: Natural forces—wind formation, wind direction, wind force, measuring wind direction, measuring wind force	Weather: Illustrate cause and effect and identify whether it is a hazard or disaster. Use graphs to illustrate patterns. Inclusion of meaning of force, pressure (especially air pressure), barometer. Reading weather maps.	Weather: Explanation of cloud/wind formations—hurricanes/typhoons, tornadoes. Historical events, predictions and consequences on various geographical regions.	Weather: Developing models of different types of wind hazards and predicted impacts. Use of instrumentation, for example, GPS and weather maps/predictions Weather forecasting/tracking. Developing an index of risk exposure and safety likelihood. Identify and integrate into models impacts of human activities
Water: Natural forces—rain, rate of rainfall, measuring rainfall quantity, flood, sea tides, high/low tides. States of matter; evaporation and condensation	Water/ice: Illustrate cause and effect and identify whether it is a hazard or disaster. Use graphs to illustrate patterns. Inclusion of the effects of water on different soil types, source and impact of pH of rain, types of erosion, role of vegetation against erosion/landslides; effects of tidal movement and water/wind on erosion; effects of rivers on erosion, evaporation, rate of evaporation versus temperature. Corrosion effect of water, especially rusting	Water: Explanation of: (a) heavy rain causing landslide; (b) Earthquakes causing tsunami. Hydrophilic and hydrophobic substances. Historical events and consequences in a geographical region. Hydraulic pressure. Graphs of amount of rain versus landslides/no. of earthquakes and magnitude versus tsunami	Water: Developing models of different types of hazards from rain or tsunami and predicted impacts. Developing an index of risk exposure and safety. Identify and integrate into models impacts of human activities

Appendix 2

LPs for natural hazards and disaster impacts

Lower Anchor			Upper Anchor
Ability to outline the impacts of previous natural hazards affecting the local community (or neighboring region/country) and ability to determine circumstances under which these are disastrous/ beneficial to people's well-being, environment and society	Ability to describe the multi-dimensional impacts of natural disasters affecting the local community (or neighboring region/ country) taking into account geographical location, population, health/well-being, social, economic, environment and identifying short-term/long-term effects	Capability to relate how local/ regional disasters affecting national/global societies, environment and economies are intertwined. Interrelating human impact, stability and risk reduction	Capability to use case studies and current events to describe local, national or international disasters and analyze how the disaster-stricken communities revitalize, highlighting social cohesion, sustainable development and human impact
Severe weather: Effects of high winds, lightning, tornadoes, tropical cyclones … on natural and human-built environments Hazard of wind effects and benefits (e.g. tropical cyclones—balance the Earth's heat, beneficial rains, breaking droughts)	Severe weather: Severity is dependent on the size and population of the geographical area affected. Interpret short/long-term impacts on people (e.g. health epidemics, families, mental illness); economics (business disruption, loss of livelihood, price increase; environment (forest defoliation, denudation, changes in geographical distribution/ behavioral adaptations of flora and fauna) and social systems (infrastructure, services)	Severe weather: flooding in manufacturing industries causes disruptions to manufacturing supply chains resulting in regional and global shortage (e.g. hard disk drives and auto parts)	Severe Weather: Examine case studies of natural hazards and impacts on social cohesion, sustainable development; suggest ways of revitalization for the disaster-stricken community (e.g. Eastern North America, Australia, Philippines)
		Linking the severity of impact to the affected area's level of development and disaster preparations. Economic and employment impacts	

Appendix 3

LPs for disaster preparedness

	Lower Anchor			Upper Anchor
Appropriate individual or group actions for hazard preparedness	Ability to describe ways people can act individually/ as groups to utilize processes/interactions reducing adverse effects of NH&DRR locally (or neighboring region/ country)	Ability to identify/perform precautionary measures taken before/during/after a hazard strikes. Develop abilities to recognize systems/ways of communication to others	Capability to link disaster agents and preparedness (risks vs. actions to take: no risk—no action; risk—action; risk—no action; no risk—action) to avoid dangers of false claims	Capability to create brochures or action plans about steps individuals, families, school/local community need to take or be persuaded to take to bolster the nation's capacity to prepare and respond effectively and seamlessly to disastrous events
Technology and engineering related to major challenges in risk reduction		Ability to identify/describe structural infrastructure features in communities/other countries protecting people from adverse impacts of NH&DRR Apply engineering process cycle for problem-solving through evaluation and redesigning	Ability to explain and relate scientific knowledge/ technological design concepts to engineering solutions in community (or neighboring region/country); analyze limitations, including community values affecting designs	Capability to use visual images (e.g. pictures, multimedia) or construct models, based on research/ creativity, to test/refine solutions for sustainability. Capability to design/ implement/evaluate engineering solutions to mitigate local/global hazard/ disaster impacts

Appendix 4

LPs for cross-functional skills

	Lower Anchor			Upper Anchor
Creativity and innovation	Ability to provide concrete examples of invention, creativity/innovation from the past within/across local/national/international communities making societies less vulnerable to NH&DRR	Ability to use existing knowledge/generate multiple new ideas, limiting impact of NH&DRR on communities	Capability to compare and support/refute creative ideas/ innovations to maximize creative efforts for the optimum benefit of communities	Capability to design/invent novel materials needed in the community to reduce the adverse impact from natural hazards, test effectiveness under different operating conditions/refine inventions; consider constraints such as economics/societal values
Futures thinking	Ability to forecast likelihood of a community, neighboring region/country hazard and people readiness to stay safe	Capability to create a vision for the future (safer, more resilient communities)	Capability to relate the current situation to the vision of a future world; analyze gaps/ways to reach an ideal world	Capability to explore a future world at systems levels; predict problems/alternative solutions; prepare plans when problems arise/actions for NH&DRR needed
Risk-based decision-making	Ability to identify action risks (e.g. staying at home despite evacuation advice) or solution (e.g. ability to design structures to withstand high winds/seismic shaking	Ability to describe aspects of risks and pre-existing conditions; posing risks, especially related to structure/function	Capability to employ risk-based analysis/decision-making (treating real dangers as dangerous, safe situations as safe) considering energy, stability and change	Capability to consider social perspectives, and take scientifically and technologically informed stand/actions relative to NH&DRR preparedness plans/ actions; indicate development of behavioral actions

Appendix 5

LPs for dispositional factors

	Lower Anchor			Upper Anchor
Adaptability and flexibility	Ability to examine views/ beliefs of experts/non-experts on NH&DRR preparations; identify errors re-decisions, based on bad information	Ability to utilize a range of coping strategies, for example, calmness, positive response to chaotic situations, endurance/ resilience toward managing unforeseen difficulties	Ability to link behaviors with societal conditions, adapting behaviors to changing conditions; not paralyzed by uncertainty	Capability to use creative/ critical thinking skills to make/ justify suggestions (e.g. improvization/recycling resources) for change; initiate/ implement change for improvement
Leadership and responsibility	Ability to embrace a sense of personal responsibility for self/others safety by participating actively in all aspects of disaster preparation/recovery efforts.	Ability to show leadership skills, for example, guiding persuading/inspiring others toward a common good (e.g. maintaining health amidst dirtiness/disorder; personal/ family safety) and demonstrating integrity/ethical behavior.	Capability to act responsibly/ uphold 'responsibility of distance', that is, being involved in planning/ organizing events raising awareness/funds to ease emergency affected suffering.	Capability to develop/maintain personal commitment to correct/avoidance behaviors/ actions generating negative impacts. Capability to manage components of a project/event geared toward community's resilience/sustainability despite high vulnerability to hazards.
Initiative and self-direction	Ability to examine natural hazards of personal interest, work with others to conduct investigations for alternative, including engineering solutions	Ability to monitor self-learning/progress searching for sustainable solutions, reducing community's hazard exposure; setting quantifiable success criteria goals; completing tasks without direct supervision	Ability to employ strategies to back resilience/coping behavior to achieve challenging goals.	Capability to make informed actions; advance skills on precautionary measures to mastery/expert level; live sustainable lives; act autonomously; demonstrate commitment to lifelong learning

Appendix 6

LPs for connectedness and behavioral actions for resilience/sustainability

Connectedness			
Ability to describe connections among existing learning on NH&DRR, ability to cope and perform precautionary measures to reduce risks; adopt positive attitudes and value disaster preparations.	Ability to illustrate how self/others thinking, feeling and doing relate to ability to handle preparedness/action and scale of risk exposure.	Capability to identify and compare effective/ineffective preparedness plans linked to individual/collective thinking, attitudes/values, actions; relate understanding/skills/dispositions toward use of technology to minimize risks exposure/disasters/needed for change	Capability to employ strategic systems thinking to hypothesize/develop community resilience (interdependence of societal aspects, for example, people's thinking/dispositions/actions); creatively prepare plans/communicate accurately scientific knowledge on NH&DRR.
Behavioral actions for resilience and sustainability			
Ability to describe societal obligations as citizens in local/national/international communities, involving activities promoting social cohesion, resilience/sustainability	Ability to make sense of societal events; how people take opportunities to demonstrate resilience/active citizenship; show solidarity/empathy to those affected by emergencies	Capability to consider nature of emergencies, undertake needs analysis, reflect on proximity when planning/organizing civic activities (i.e. volunteering, donations)	Capability to propose and implement practical and sustainable projects/activities amplifying actions, improving current risk reduction activities/aid practices